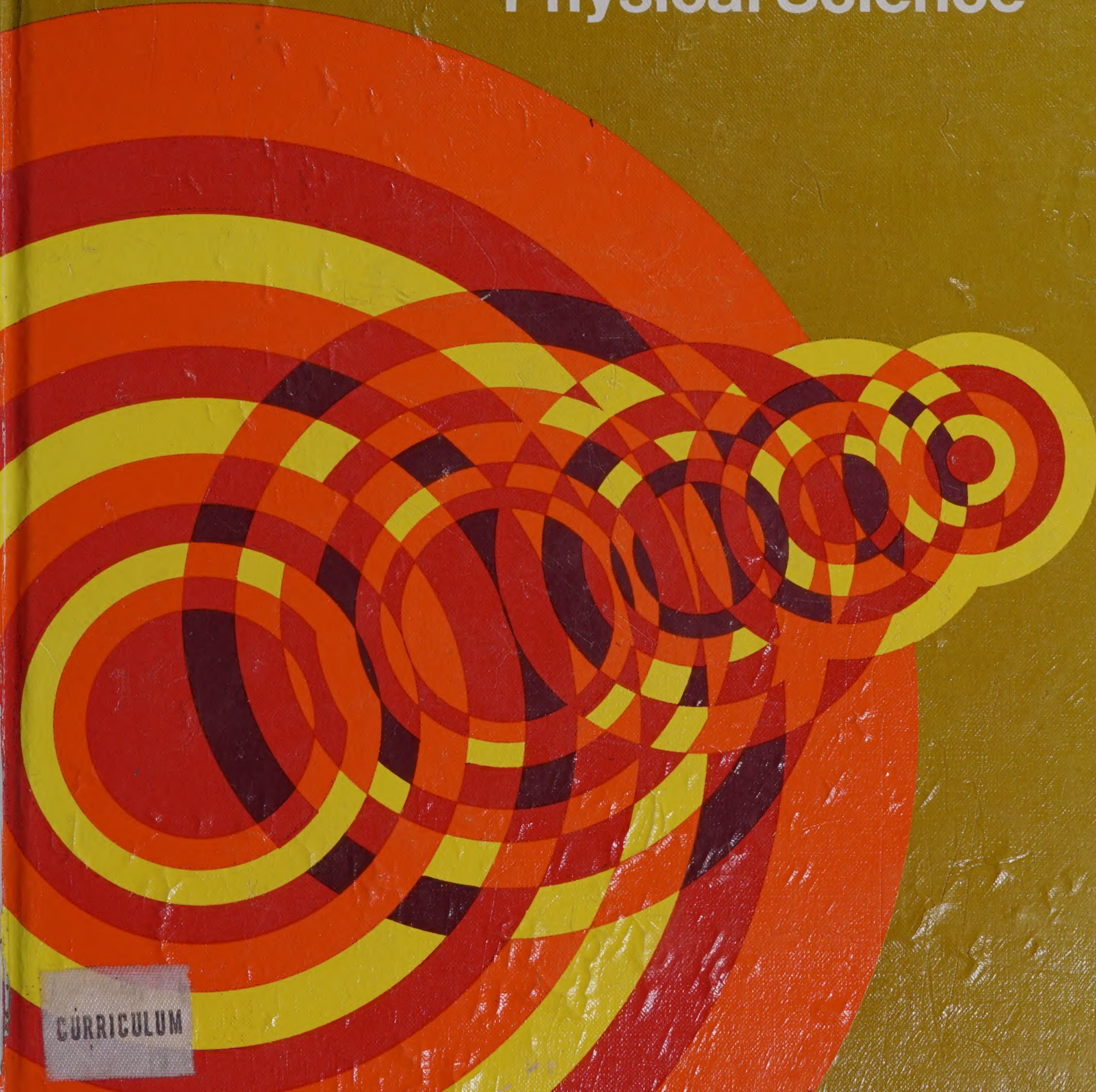
Spaceship Earth

Physical Science



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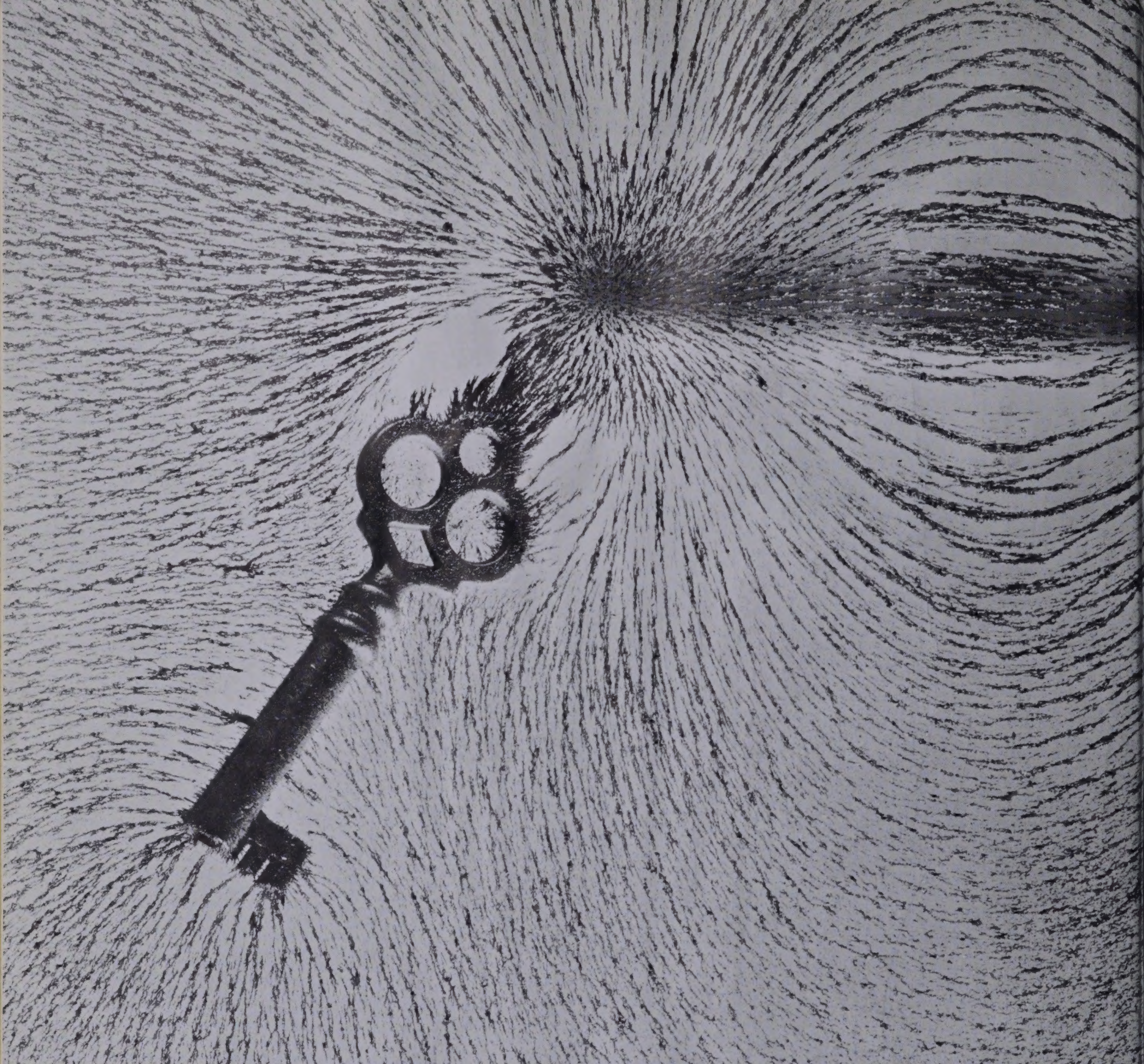

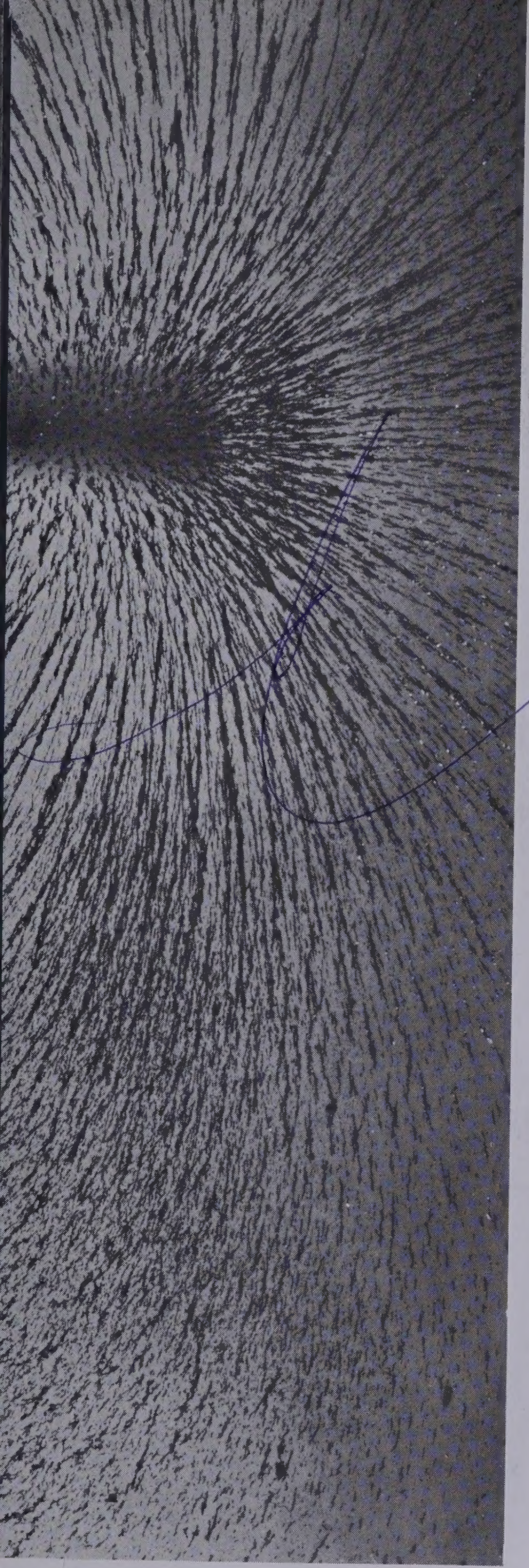

Spaceship Earth
Physical Science

Faith Fitch Hill

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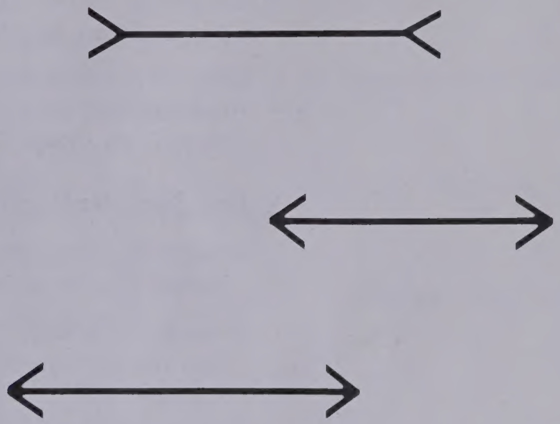
Preface to the Student

Two of these lines are the same length. One is different. Can you pick out the ones that are alike? Choose and then measure them.



Did the answer surprise you? When you try to understand the physical world around you, it is not always easy to be sure of the facts. So you look carefully and you measure too. Then you try to draw conclusions.

That is what you will do in this book. You will look at and handle many things. Nearly everything you study will be related to things you see and do every day. You will begin to understand better how things work—simple things, like a baseball, and more complicated things like electric circuits and the chemicals in food. You will not just read about them; you will use them and see how they behave. This is a do-it-yourself-and-enjoy-it book, not a read-about-it-and-memorize book.

After all, that is how a scientist learns things, so why shouldn't you?

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Unit One

Motion

Chapter 1

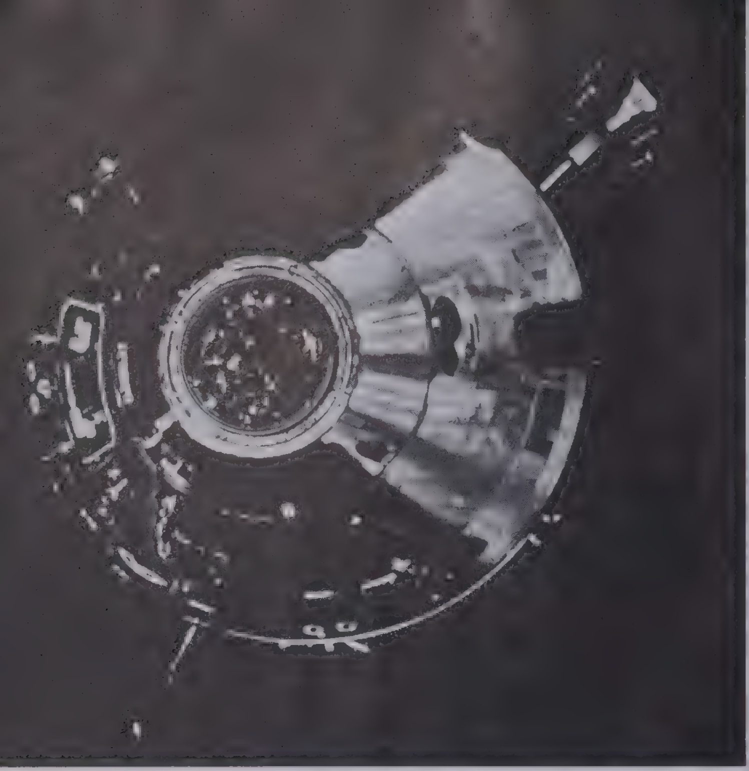
The Way Things Move

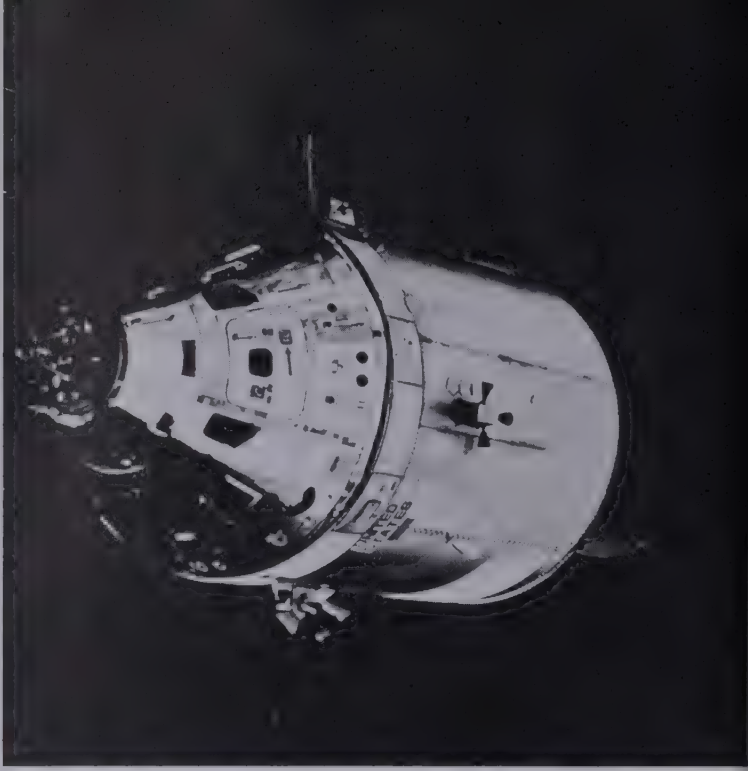
"It was the most beautiful thing there was to see in all the heavens."

That was Jim Lovell talking. He was telling about his trip to the moon. He had been looking back at the earth.

Jim Lovell was going faster than he had ever gone in his life, but he was not afraid. If his ship went too fast, it might go past the moon. If it went too slowly, it would fall back to earth. But he knew that people on earth were tracking the ship. They would tell him when to speed up and when to slow down and when to change course.

People in the control center on earth know a lot about how things move. That is why they can tell the astronauts what to do. It takes a long time to learn enough for a job like that. But in this chapter you will learn some of the things control center people need to know about motion.





Apollo astronauts in the Lunar Module (LM) took these photographs of the Command/Service Module (CSM).

Pictures Show Motion

1-1 What the space men see

In the four photographs above, what do you notice that tells you things are moving? In your science notebook, make a list of everything that seems to show motion. Your list should look like this:

Today's date ____________

1-1 What the space men see
Things that show motion
1.
2.
3.

One thing you notice in the pictures is that the size of the CSM seems to change. This is called an observation. An **observation** is something that you discover by looking or touching or smelling or tasting or hearing.

If you also put down on your list that the CSM was moving away from the camera, that is not an observation. It is an interpretation. An **interpretation** tells why or how something happens.

Go over the lists that you and other students in the class have made. Sort out the observations from the interpretations. Write them in a chart in your notebook like this:

Today's date ______________

1-1 What the space men see
Motion as seen from the LM

Observations	*Interpretations*
1. The CSM looks smaller in some pictures than in others.	1. This is because the CSM was moving away from the camera.
2.	2.
3.	3.

The first observation and interpretation are already listed. Add the observations and interpretations made by all of the members of your class.

1-2 Observations that show motion

Motion is shown in two ways in the space pictures. The first way is by a change in position. For example, the CSM is seen head on in the first picture, and from the side in the

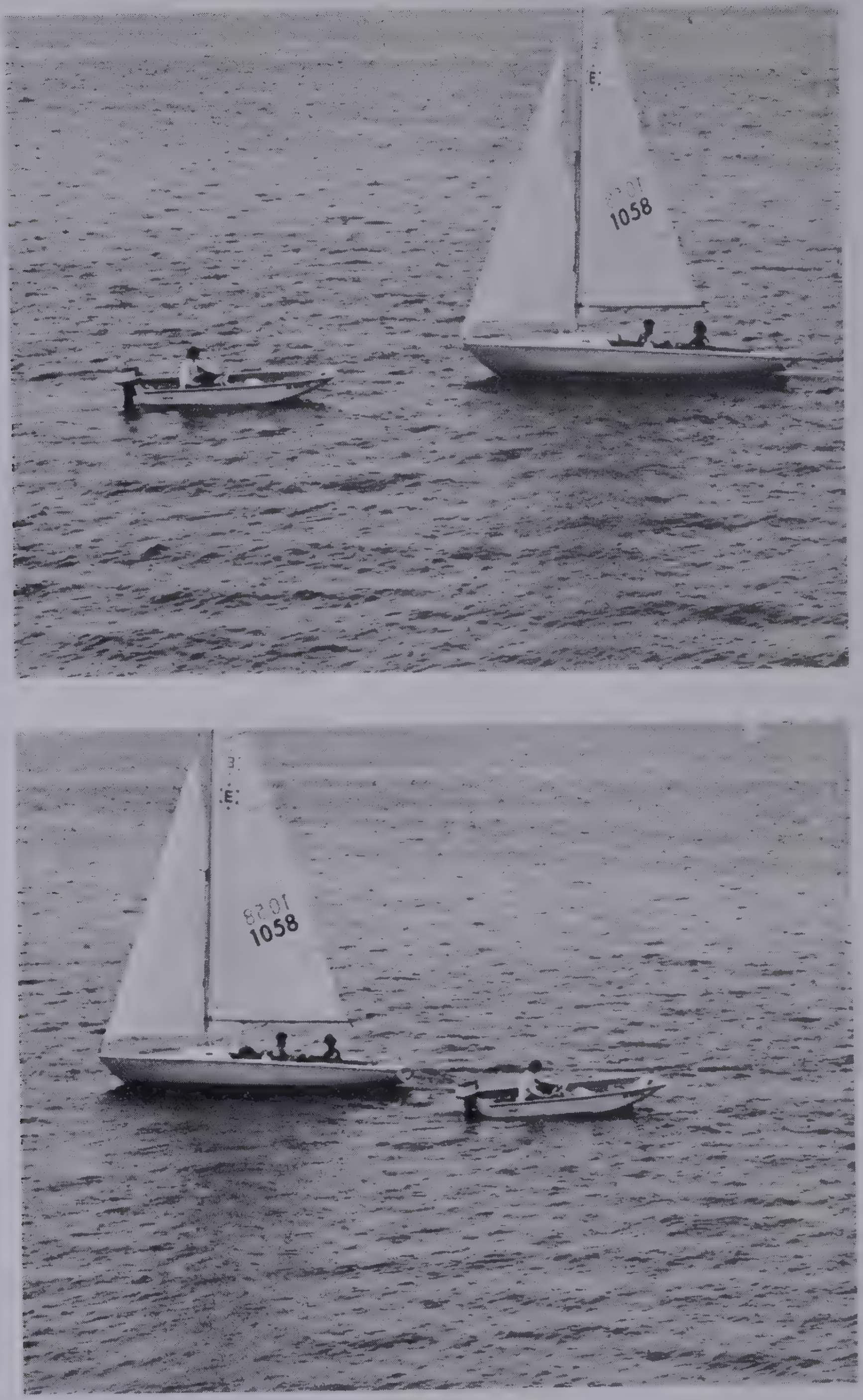


Figure 1-1 *What moved here? One boat, both boats, the photographer?*

next. This observation always tells you that something is moving. The second way is by a change in size. The CSM seems smaller in some pictures than in others. This observation does not always mean that something is moving. For example, a balloon with a slow leak will look smaller and smaller. It is not moving away from you. The correct interpretation is that the balloon is shrinking.

If a band is marching toward you, you hear a louder and louder sound. If you cannot see the band, can you be sure it is moving? Might there be a different interpretation? Think of other examples, using the senses of sight, sound, or smell.

1-3 What moved?

★ This game is played by two teams. While team A watches, team B should put their heads down. Now a member of team A moves one or more of the objects on the front desk. Then team B members look up and try to guess what moved.

Later team B will do the moving. Team A will do the guessing. ★

At first you may be only guessing. As you play the game, you should learn how to tell what things were moved.

One of the photographs in Figure 1-1 was taken later than the other. What moved? Was it the big boat, the small boat, the photographer, something else? Did more than one thing move?

Now turn the page to Figure 1-2. Here it is easy to tell what moved. You know that one of the boats moved because it has changed position compared with the background. You know that the photographer did not move because the shore is still in the same place compared with the background.

In order to tell what is moving, you need to have a background.

1-4 You can change the background

Imagine that you are on a bus. You roll a toy car down the aisle from the front of the bus to the back. You use the bus for a background. Inside the bus the toy car is rolling toward the back at a speed of five miles per hour (Figure 1-3).

A boy stands beside the road watching the bus. He uses the surface of the earth for his background. He sees the bus going north at 40 miles per hour. Now imagine that the bus has glass sides. The boy can see your toy car. From his point of view, is the toy car going north or south?

Now you roll the toy car faster. On the floor of the bus the car is going south at 40 miles per hour. The boy beside the road is watching. From his point of view, what is the toy car doing? From your point of view, inside the bus, what is the boy doing?

During a telecast from a spaceship, an astronaut held up a flashlight and then let it go. The flashlight seemed to float in the cabin. With the spaceship as background, the flashlight was motionless. From the point of view of someone on earth, the flashlight was moving away from earth at thousands of miles per hour (Figure 1-4).

You can choose anything you want for your background. Then you pretend that this background is not moving. The background that you choose, the one that you pretend is not moving, is often called the **frame of reference.**

1-5 We are in a dizzy whirl

Thinking about frames of reference can be fun. It can drive you crazy too. For example, you walk across a room. Just a nice, straight line, with the earth as the frame of reference. But the earth is turning, so you are moving in a circle too. And the earth moves around the sun. Maybe someone watches from a frame of reference outside our solar system. He would think you are doing a fancy dance.

But that is not the end. The sun is in a huge bunch of stars called a galaxy. The sun makes a big circle around the center of the galaxy. The dance gets crazier.

Does anything stand still? Is there a frame of reference that does not move? No one knows.

So let's not worry about it. When you do experiments on earth, use the surface of the earth as the frame. If you plan a trip to the moon or out to a distant star, you will use another frame.

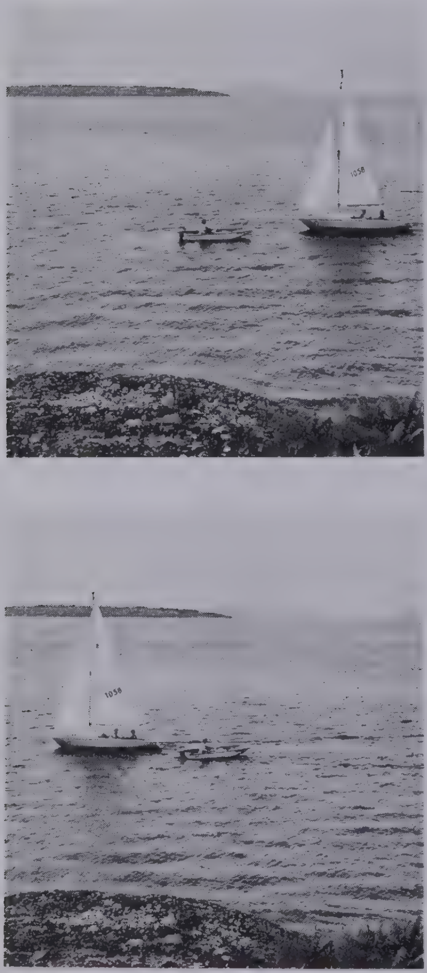


Figure 1-2 *These photographs are the same as Figure 1-1. Now can you tell what moved?*

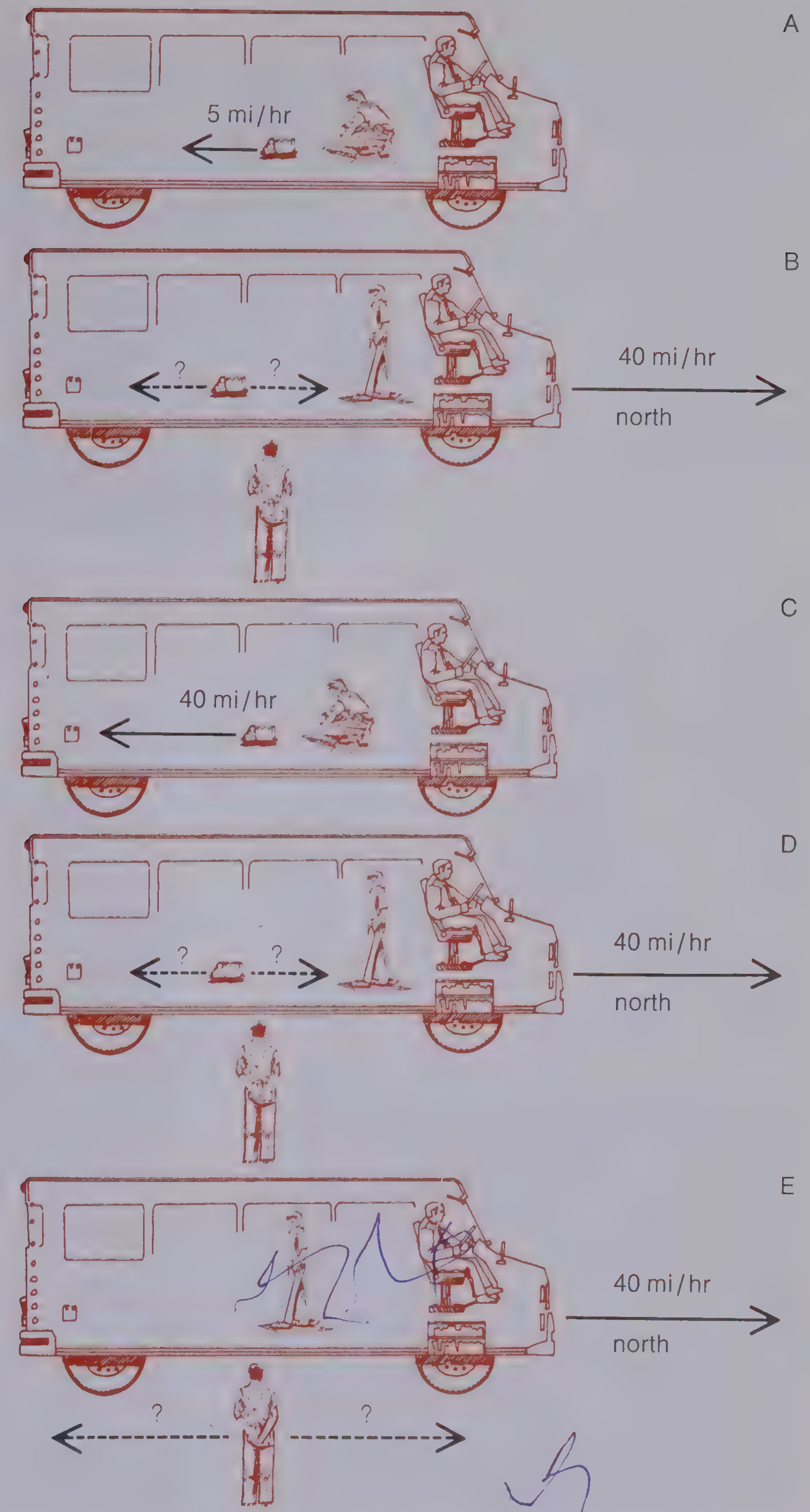


Figure 1-3 (*A*) *You roll a toy car toward the back of the bus. With the bus as the background, the toy car is going 5 miles per hour.* (*B*) *The boy beside the road uses a different background. Which way does he see the toy car go?* (*C*) *You roll the toy car faster—at 40 miles per hour.* (*D*) *Now which way does the boy outside see the toy car go?* (*E*) *Which way do you see the boy go?*

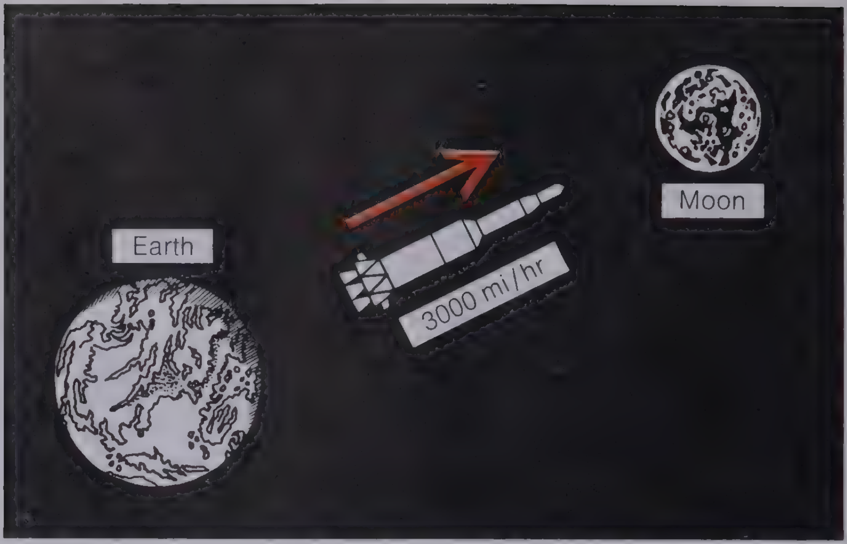


Figure 1-4 *Every hour the capsule, the astronaut, and the "motionless" flashlight are 3000 miles further from Earth.*

Did You Get the Point?

Everyone makes observations. You do it in your daily life, not just in a classroom.

You often make interpretations to explain your observations.

How you interpret observations about motion depends on the frame of reference you choose.

The surface of the earth is often used as a frame of reference.

What Have You Learned?

1. In the pictures on pages 2 and 3, the position of the CSM in the first picture is not the same as in the second picture. Give two possible interpretations.

2. In the pictures on pages 2 and 3, the CSM in the second picture is smaller than in the first picture. Give two or three possible interpretations.

3. Close your eyes for five minutes. How many moving things can you detect? How did you know that there was movement?

4. Two buses are going in the same direction at the same speed side by side. Use the inside of one bus as the frame of reference. What is the other bus doing?

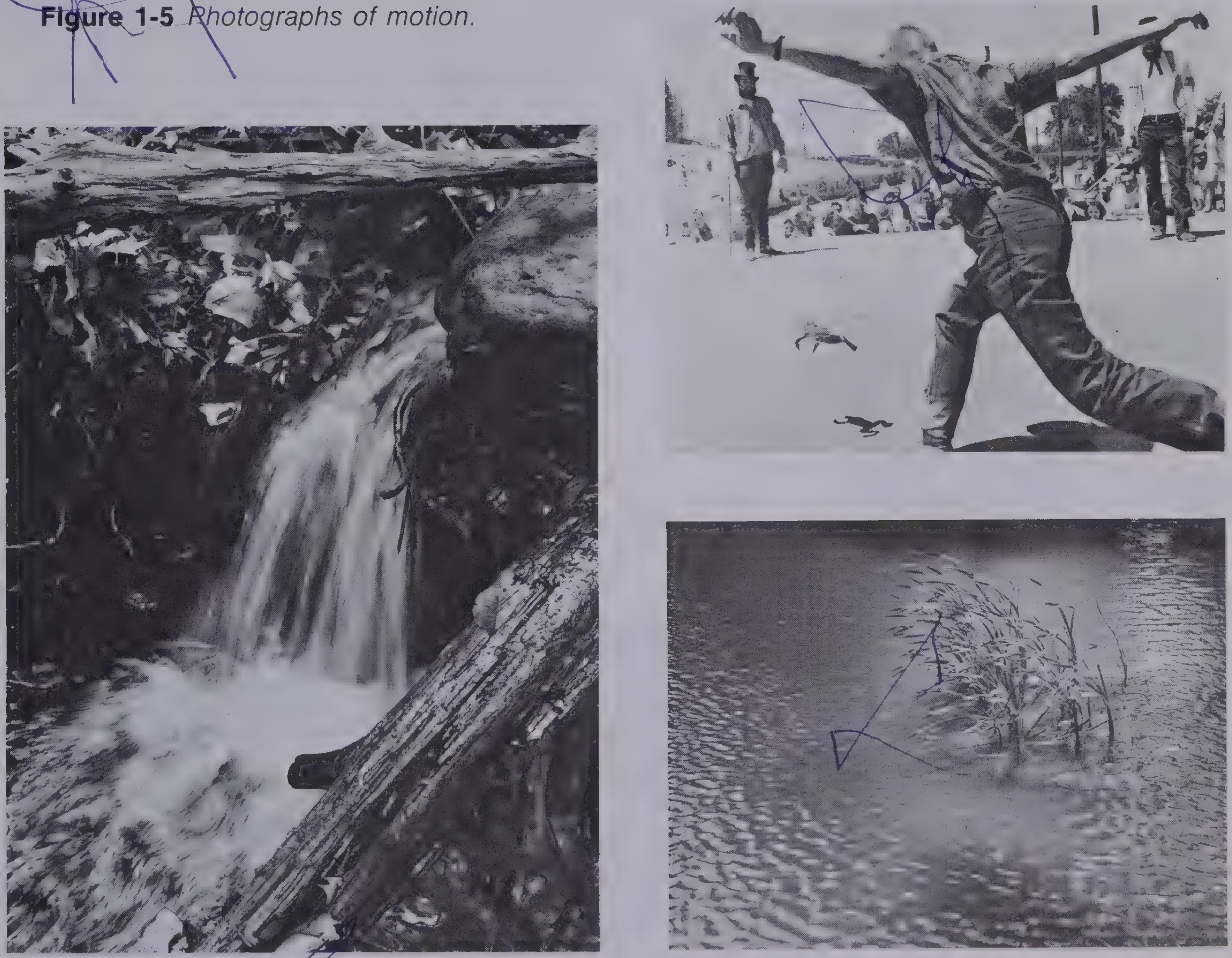
5. Astronomers know that the earth and a certain star are getting farther apart. What is moving, the earth, the star, or both? Is there any way to tell for sure?

How Do Things Move?

1-6 Keep your eye on the ball

The pictures in Figure 1-5 all have the earth as the frame of reference. In every picture there is motion. Why are these things moving? How did the motion start? How long will it go on?

Figure 1-5 *Photographs of motion.*



Let's start with questions that are easier to investigate. Must you push something to make it move? If you get it started, and then stop pushing, what happens? If you push a ball that is sitting on a smooth surface, what does it do? How do you make it turn a corner?

Materials
balls, other objects that roll or slide, surfaces

★ Make some things roll or slide and watch what happens. Make two columns in your notebook for your observations, like this:

What did someone do?	*What happened?*
Example: Push a steel ball that was lying on the floor.	*Example:* The ball rolled in a straight line until it hit the wall, and then bounced back in a straight line. ★

1-7 Make guesses

When you try to interpret your observations, ask questions that start with "Why?" Why did the balls move? Why did some balls roll farther than others? Why did the balls usually go in straight lines? Why did they sometimes curve?

Make guesses about the answers. Some students pushed and pulled carts. Here are some guesses they made.

"I think," said Jane, "that things only move when I push them."

"Or pull them," added Hank.

"Right," said Jane.

"But when I pushed my cart, it kept on going after I stopped pushing," said Tony.

"But then it stopped, didn't it?" asked Alice.

"Yes, but Jane said things only move when you push them. Then they ought to stop right away when I stop pushing."

"That's right," said Kevin. "My guess is that things naturally keep on going when you stop pushing."

"But why did my cart slow down then?" asked Jane.

"I don't know, but I think something stopped it. Friction, maybe."

Discuss these guesses in your class. Can you make others?

A guess like these, used to explain the observations, is called a **hypothesis** (hye-POTH-uh-sis). Jane and Kevin made two different hypotheses (hye-POTH-uh-seez, the plural of hypothesis).

Jane's hypothesis is that maybe things move only when they are being pushed or pulled. Kevin's hypothesis is that maybe things start to move when they are pushed or pulled, but when they are moving, they keep on going unless something stops them.

1-8 Test the hypotheses

Hypotheses should be tested. For example, suppose Paul keeps beating up kids at school, including you. You guess this is because nobody will be his friend. You say, "If I try to be his friend, maybe he will stop beating me up." So you bring candy to school and give it to Paul. You are testing the hypothesis. He does not beat you up. You think you have a good hypothesis. The next day he says, "Where's my candy?" You don't have any, but you ask him to sit with you at lunch. No good. He is mad and beats you up. You decide your hypothesis needs a little changing.

Columbus made a hypothesis: "The earth is round." He said, "If the earth is round, I can get to India by sailing west." Notice the "if." Then he tested the hypothesis by sailing west. Did his trip show that his hypothesis was a good one?

Now look at Jane's hypothesis. She thought that maybe things move only while they are being pushed or pulled. If that is so, then they should stop moving right away when the pushing or pulling stops. But they don't. So either the hypothesis is wrong, or it has to be changed in some way.

Kevin's hypothesis says that once something starts moving it keeps on unless something stops it. He thought friction might be stopping things. If that is true, then a rolling ball should go farther when the friction is low than when it is great.

You do not have enough information yet to test Kevin's hypothesis. Your observations were based on a few quickly-done experiments. You think some things rolled farther than others or went farther on some surfaces. But you pushed some harder than others. Some were heavier and some were smoother.

Materials
pingpong ball, tube, meter stick, books

★ To check Kevin's hypothesis you will use the same pingpong ball each time and you must see that it gets the same start each time. Figure 1-6 shows how to do this. The ball rolls down the tube because the earth is pulling it. Why is it important to have the same height each time? When the ball rolls onto the floor, does the earth still pull it?

Make a table for recording your measurements in your notebook. Here are some questions to be thinking about while you do the measuring.

Did the ball slow down every time?

Did it go the same distance on all surfaces?

Were the surfaces alike?

Does a surface push on things that move across it? In which direction?

Which surface had the most friction? Which had the least? How was this related to distance?

Did the ball go in a straight line or a curve?

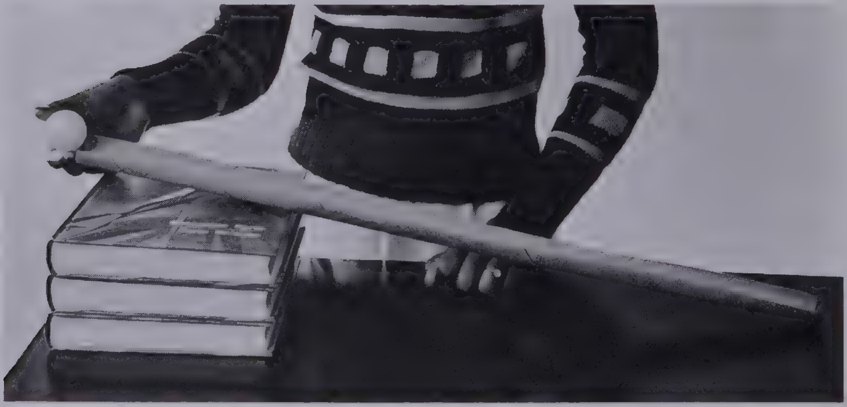


Figure 1-6 *Measure how far the ball goes each time.*

The tennis player shown here is Evonne Goolagong.

PROFESSIONAL ATHLETE

Why does a grounder move faster on Astroturf than on grass? How does spin affect a bowling ball or a tennis ball? Can you throw a football farther on a dry day or on a humid day? To answer questions like these, professional athletes need to know a lot about the way things move.

The professional athletes that most of us know best play football, baseball, basketball, or hockey. These are all team games. Many more people, including almost all the female professional athletes, compete in individual sports—golf, tennis, rodeo, boxing, bowling and so on. Jockeys, auto racing drivers, and professional chess players are considered to be professional athletes.

To succeed in certain sports you need to be born with some qualifications. Basketball players have to be tall. Jockeys have to be light. All athletes depend on good coordination and quick reflexes. But, no matter what the sport, a professional athlete must work to stay in excellent physical condition. It takes much concentration and determination to win.

Now think about Jane's and Kevin's hypotheses while you answer some more questions:

Did the ball start moving when it was pulled?

Did it stop moving as soon as the pulling stopped?

Was there ever a time when nothing was pushing or pulling on the ball?

What happened when friction was less?

What do you think the ball would do if it rolled onto a surface where there was no friction?

Which hypothesis seems better?

Write in your notebook a summary of your interpretations and conclusions. ★

1-9 What is a force?

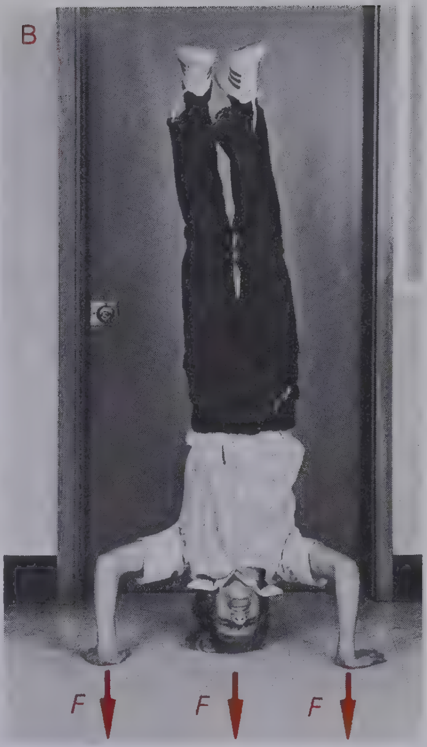
The pull of the earth on the pingpong ball was a force. The push of friction that slowed it down was a force. Figure 1-7 shows some other forces. Notice that each force has a direction.

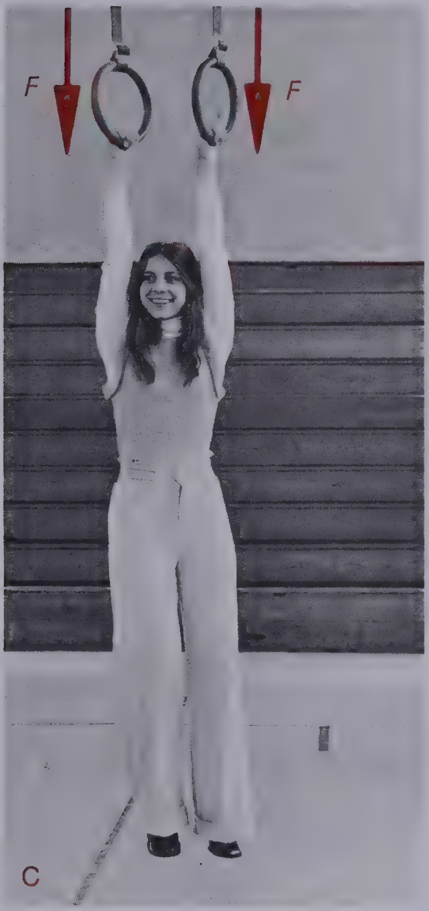
Forces do things to objects. The force of your hand on a cart makes it move. A rough rug applies a force that makes a rolling ball slow down. Both of these forces change the speed of the object.

A force can also change the direction in which an object is going. Most of the time the pingpong ball rolled in a straight line. Sometimes a ball bumped into the wall. The wall pushed the ball and changed its direction. In your activity what else applied a force to change the direction?

If you squeeze a rubber ball in your hand, you apply forces. But the ball does not change speed or direction. It changes shape. This time the forces on one side are balanced by forces on the other side. Then the only thing that happens is a change of shape.

A good way to define something is to tell what it does. A **force** always acts in a particular direction and it either changes the speed, changes the direction of motion, or changes the shape of an object. Sometimes a force does more than one of these things. Tell what the force is doing in each of the pictures in Figure 1-8. If forces cancel each other out, they are called **balanced forces.** Which pictures show balanced forces?





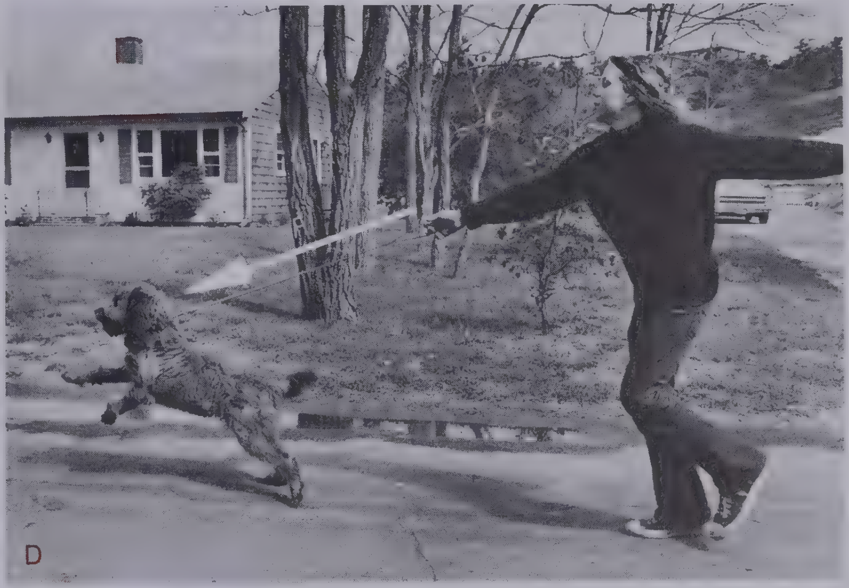


Figure 1-7 *(A) To pull a wagon you apply a force forward on the handle. (B) When you stand on your head, you apply a force down on the floor. (C) The ropes apply an upward force. (D) The dog is applying a force forward on the leash.*

Figure 1-8 *(A) The bat applies a force. What does it do to the ball? (B) This tug-of-war is a tie. The door is not moving. (C) What did the force of the player's hand do to the ball? What did the force of the backboard do to it? (D) The force of the kick changed the ball. What did the ball do next?*

1-10 Newton's law

About the time when New England and New York were settled by Europeans, an Italian scientist, Galileo, did an investigation like yours with rolling balls. He made the surface smoother and smoother. The balls went farther and farther. He decided that the ball would go forever in a straight line unless an unbalanced force was applied.

Later an English scientist, Isaac Newton, wrote a book about motion. He included Galileo's discovery. It came to be called **Newton's first law of motion.** One good way to state the law is this: If an object is not moving, it will not move unless an unbalanced force is applied to it. If an object is moving, it will keep on moving at the same speed in a straight line unless an unbalanced force is applied to it.

A law in science is not like a law made by a government. A government law tells you what you ought to do. You ought to stop for a red light. You ought not to steal. You ought to pay taxes. A **scientific law** tells how things behave. If objects do not behave the way a scientific law says they do, then the law is wrong, not the objects. Newton's law is a scientific law.

1-11 People use Newton's law every day

Suppose your mother asks you to clear the table. You are in a hurry. You grab a plate and start quickly to the sink. Crash! The knife and fork fall to the floor. You applied an unbalanced force to the plate, giving it speed. You did not apply a force to the knife and fork so they remained at rest. The plate slid out from under them. Down they went.

You are in a car. When it starts to move you feel pushed back in the seat. An unbalanced force has been applied to the car. It starts to move. The unbalanced force was not applied to you, so you do not start to move. However, the back of the seat, which is part of the car, is moving. It hits you and gives you a push. You are not pushed back in the seat. The seat is pushed forward into you.

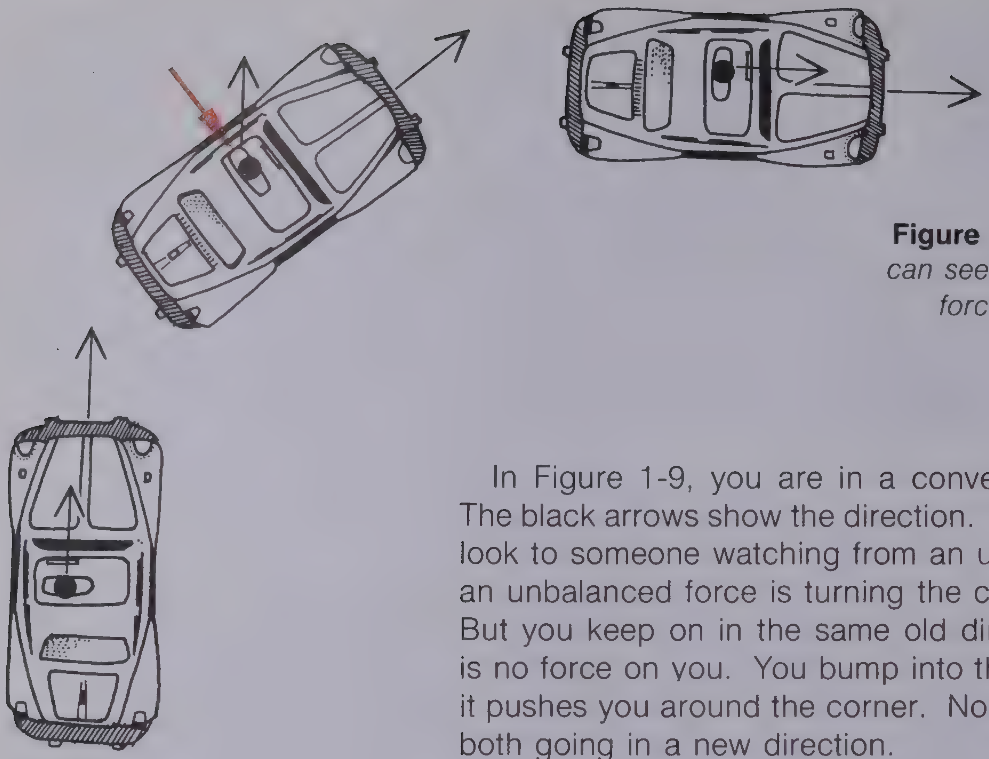


Figure 1-9 *From overhead you can see that the car applies the force that pushes the driver around a corner.*

In Figure 1-9, you are in a convertible that is moving. The black arrows show the direction. This is how you would look to someone watching from an upstairs window. Now an unbalanced force is turning the car to a new direction. But you keep on in the same old direction because there is no force on you. You bump into the side of the car and it pushes you around the corner. Now you and the car are both going in a new direction.

Figure 1-10 shows some easy tricks that use Newton's first law. You need practice to make them work well.

Practice this one too. Put a small match box in the center of a sheet of stiff cardboard. Hold the cardboard level and walk slowly, then faster, without disturbing the box. Then stop very suddenly. What happens? Why? How is this like something that may happen to you when a car stops suddenly?

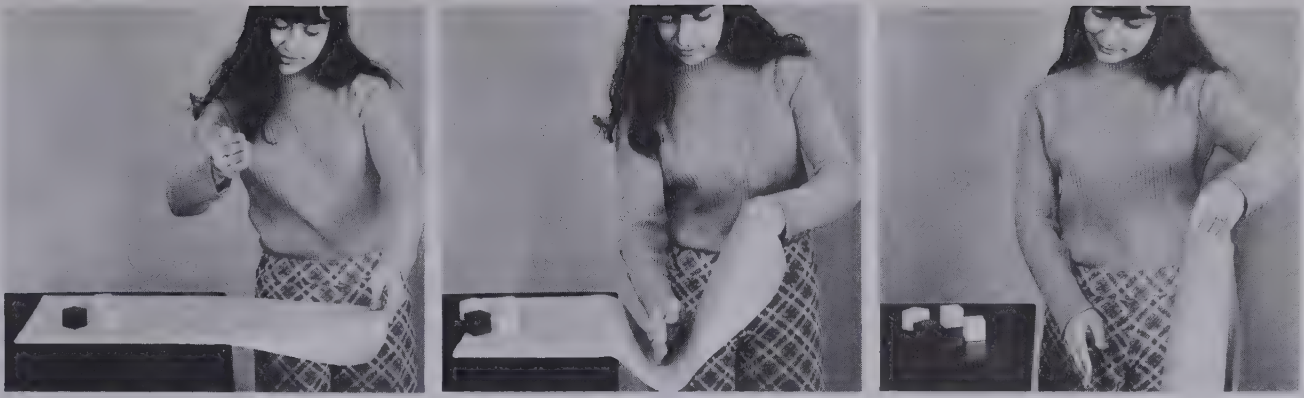
Did You Get the Point?

You often make guesses (hypotheses) to explain observations.

You test a hypothesis by saying, "If my hypothesis is true, then a certain thing should happen." Then you see if it does happen.

A hypothesis that passed your test is this: An object does not start to move unless an unbalanced force starts it. If an object is moving, it keeps on at the same speed in a straight line unless an unbalanced force changes the speed or direction.

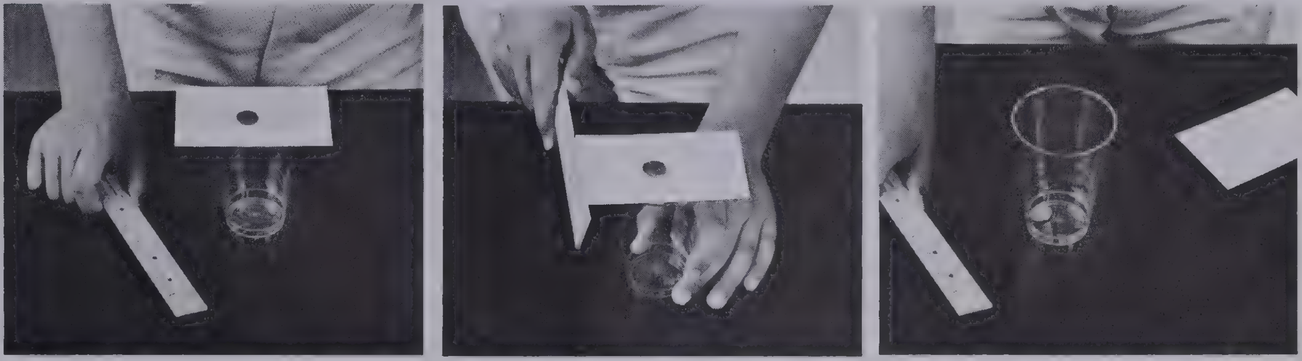
Figure 1-10



(A) Put some small objects on one end of a long piece of paper. Hold the other end.

Hit the middle of the paper with the edge of your other hand. Hit hard and fast.

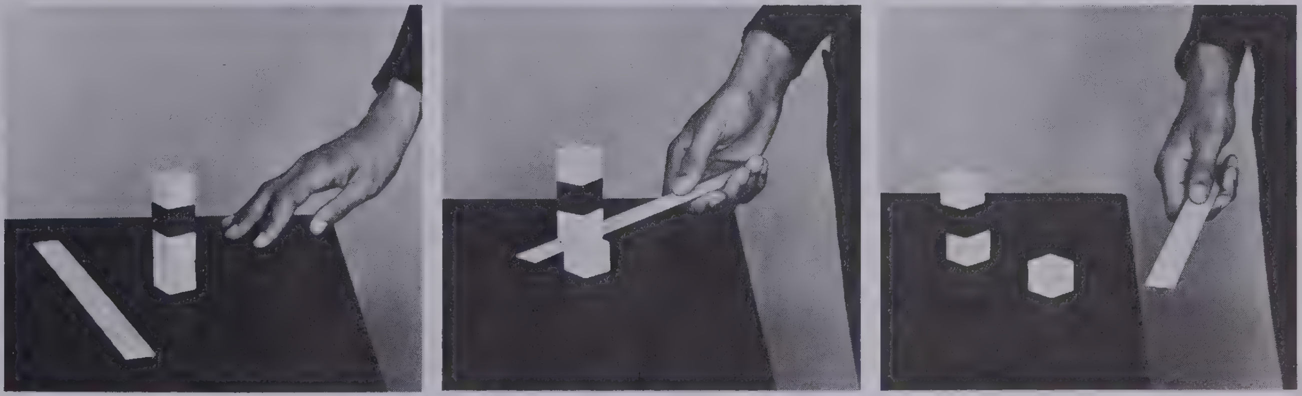
Why do the objects stay on the table?



(B) Put a card over the top of a plastic glass. Place a coin on the middle of the card:

Hit the card sharply with a ruler.

Why does the coin drop inside the glass?



(C) Make a neat stack of smooth blocks.

Hit the bottom block sharply with a ruler.

Why do the rest of the blocks stay in a stack? Try this trick again with a higher stack.

What Have You Learned?

1. Invent an experiment to test the hypothesis that when an object slides it keeps on going unless something stops it.

2. When you throw something straight up in the air, what is the direction of the force you apply?

3. The engine of a spaceship stops soon after the ship leaves the earth. How does the spaceship get to the moon?

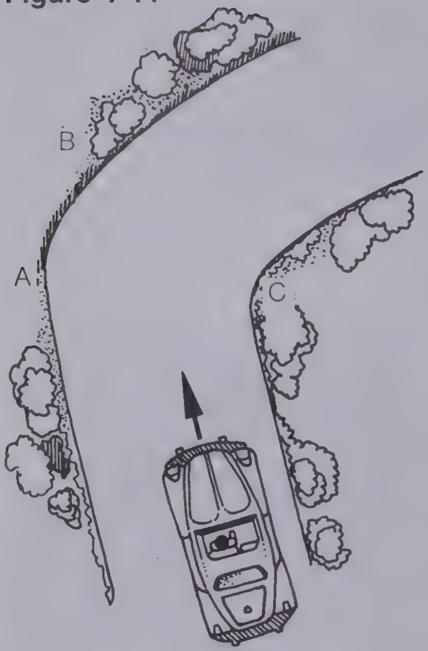
4. A box is alone in the center of the floor of a moving truck. The truck stops suddenly. What happens to the box? Why?

5. Why should seat belts remind you of Newton's first law?

6. A car moves at a steady 50 miles per hour on a straight level road. Are the forces balanced or unbalanced?

7. A car goes along a road, as shown in Figure 1-11. It skids on the curve. Will it go off the road at A, B, or C? Explain.

Figure 1-11



SKULLDUGGERY

1. Look around the room or out the window. Choose a person or an object. Make three observations, and make an interpretation from each observation.

2. Find the right word for each blank in this story. Notice that some places have more than one blank together. To help you, here is the first letter of each word:

NFLSUFPFRFRMFFD

Mr. Hernandez and his son Joe finished loading the truck. As Mr. Hernandez started to drive the truck away, there was a bump. A box had fallen off.

"We forgot ____ ____ ____," said Joe.

"There's no law says I've got to shut the door," said his father.

"No," replied Joe, "it's not a state law, it's a ____ law. It says that things don't start to move unless an ____ ____ acts on them. When the truck started, nothing ____ the box, so it stayed where it was. That's why it fell."

"But the box slid back in the truck. It didn't stay where it was."

"That depends on your ____ of ____," said Joe. "If I'd been inside the truck, I'd agree with you. But from the ____ of ____ of the surface of the earth, the box didn't ____."

"Well, it would move if I shut the door. Explain that if you're so smart."

"That's easy. Then the door would exert a ____ on the box. The ____ would be in the ____ the truck was going. So the box would have to go too."

FOR FURTHER READING

Barrow, George. *Your World in Motion.* New York: Harcourt Brace Jovanovich, Inc., 1956. Motion in the world and its effects on mankind.

Hamilton, Russel. *Science, Science, Science.* New York: Franklin Watts, Inc., 1960. Introductory history of science.

Poole, Lynn. *Science the Super Sleuth.* New York: McGraw-Hill, Inc., 1954. Dramatic part science plays in crime detection.

Valens, Evans G. *Motion.* New York: World Publishing Company, 1965. Well-illustrated to explain scientific laws of motion.

WHAT'S NEXT?

A spaceship blasts off for the moon. In a few minutes the engines are turned off. The ship is coasting through space. However, it does not go in a straight line. Unbalanced forces are acting on it. They change its speed and make it go in a curved path. Do you know what these forces are? You will learn about them in the next chapter.

Chapter 2

How Things Fall

The diver is falling a long way. As he falls, what happens to his speed? Does it stay the same all the way down, or does he fall faster and faster? Will he be hurt when he hits the water? What would happen if he landed on dry ground?

How about the parachute jumper? He has fallen much farther than the diver. But when he lands, he will not be hurt. Why?

In this chapter you may find the answers.

Fast and Slow

2-1 How fast can you run?

Materials
stopwatch, measuring tape

★ Measure out a distance and have someone time you. If you do not feel like running, try walking, and see how long it takes. Write the distance and the time in your notebook.

Now find your speed. The rule is

$$\textbf{speed} = \frac{\text{distance}}{\text{time}}$$

If you went 20 meters in 5 seconds, your speed was 20 meters ÷ 5 seconds. The answer is 4 meters per second (4 m/sec). *Per* means *divided by,* and tells how you got the answer. ★

Meters and seconds are called units. A **unit** is a small quantity used to measure bigger things. The meter is a unit for measuring distance. The second is a unit for measuring time. When you divided 20 meters by 5 seconds, you got 4 meters per second. You had to write *meters per second* as part of the answer to show that you were using one meter per second as your unit for speed.

There are other units for speed. In the United States a car might move at 60 miles per hour. That is almost 100 kilometers per hour. Spaceships leave the earth's atmosphere at about 7 miles per second.

Look in an almanac for the latest record for the 100-meter dash. Calculate the speed. How does it compare with yours?

2-2 How fast do things fall?

★ The ball in Figure 2-1 was photographed while it was falling. A light flashed when the ball started to fall. That took the first picture. One tenth of a second (0.1 sec) later the light flashed again, taking the second picture. Each tenth of a second there was a flash. You can use this picture to find the average speed of the ball during each tenth of a second.

Put the edge of a piece of paper along the line of the balls. Mark the position of the lowest part of each ball on

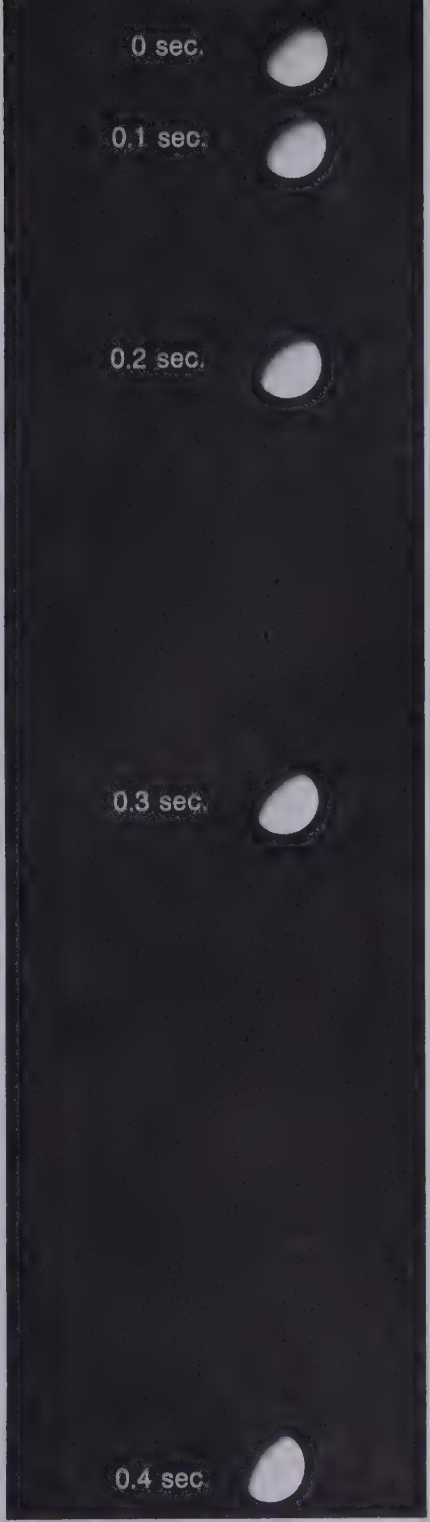


Figure 2-1 *This multiple-exposure photograph shows a ball falling in a flashing light. Did the ball always fall the same distance between flashes?*

the paper. Then use a ruler to find the distances. Make a table for your notebook like the one below. The first part has been filled in to show you how to do it.

between	time (sec)	distance (cm)	speed (cm/sec)
0 sec and 0.1 sec	0.1	1.1	11
0.1 sec and 0.2 sec			
0.2 sec and 0.3 sec			
0.3 sec and 0.4 sec			

What does the table tell about the speed of a falling ball? Does it increase? Decrease? Stay the same? ★

2-3 What about Newton's law?

In Section 1-9 you found that objects do not change speed or direction unless there is an unbalanced force. This is Newton's first law of motion. Now you find that a falling ball goes faster and faster.

Maybe the ball disobeys Newton's law. Not really. Notice the "unless" in the law. There *is* an unbalanced force pulling the ball. The earth is doing the pulling. The pull is called the **force of gravity.** The earth pulls all the time. This unbalanced force makes the ball go faster and faster.

Isaac Newton lived at the time when the colonies of North America were first being settled. He was a college student at Cambridge, England, when a terrible disease spread through the country. Many people died and the University closed. Newton went home to his mother's farm. He helped with the farm work and read and thought.

There is an old story that when he was resting under a tree he saw a falling apple. This made him think about gravity. People already knew that things fall because the earth pulls them. However, people thought that gravity works only on earth. They said that objects like the sun and moon and stars obeyed different laws.

Newton thought that maybe gravity applies to everything. It was hard to test this hypothesis. Newton could not hang up two balls and say, "See, they attract each other." The force is very small. Newton could not measure it with his equipment.

Newton did something very clever to test the hypothesis. He looked at the moon and said, "If my hypothesis is correct, then the moon travels around the earth because it is attracted to it. Otherwise it should go in a straight line. I will use my hypothesis to see what the path of the moon should be. If it agrees with what the path really is, my hypothesis is good." He found that it did agree.

2-4 How can the force of gravity be measured?

The earth pulls you. It pulls your shoes and your pencil and a rock and your house. There is another name for this force. It is *weight*. The **weight** of anything on the earth is how hard the earth pulls it.

★ You can build a scale to measure weight. The pictures in Figure 2-2 show you how to do it.

Materials
pencil, 2 rubber bands, thread, paper cup, several objects all alike, book, cardboard, paper, felt tip pen

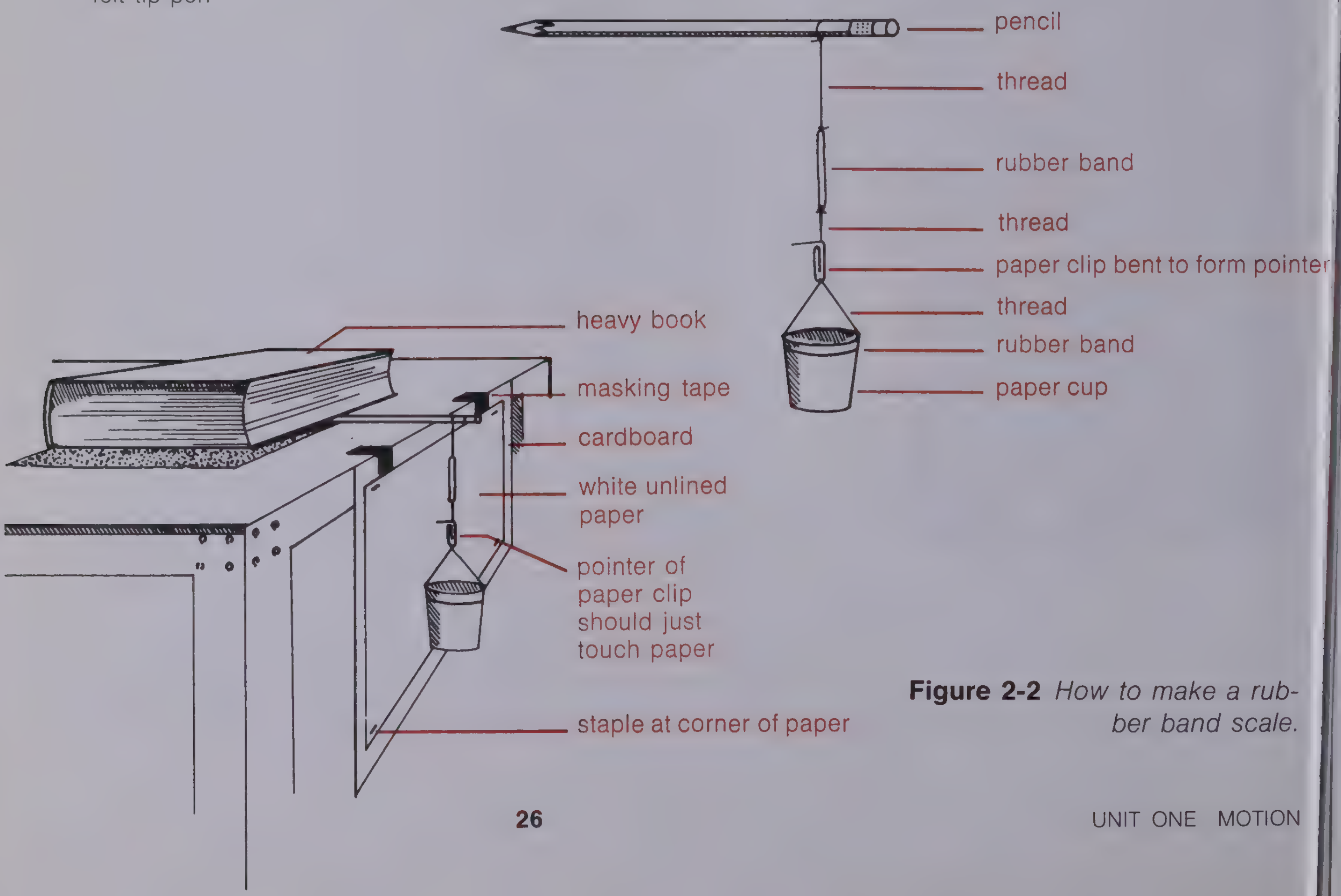


Figure 2-2 *How to make a rubber band scale.*

When the scale is finished, turn the cup gently until the pointer just touches the paper. Without touching the scale, put a dot at the exact place where the pointer touches the paper. Use a felt tip pen. The point you made is the zero point. Write "0" next to it. It shows where the pointer is when you have no weight added to your scale.

You have several objects all alike. Put one of them in the cup. The pointer will move to a new position. Mark it with your pen. Write "1" next to the mark you just made. This mark is for one unit of weight. The unit may be the weight of one bottle top, one marble, or one candy drop. Remove the object from the scale. Place another object like it on the scale. Notice where the pointer goes. Repeat this with each of the objects. Remove the object on the scale before you put the next one on. What does the pointer do each time? Why?

You have several objects that weigh one unit. Place these objects on the scale one at a time. The pointer will move to new positions. Mark each of the positions. Number them in order from 0 to the last mark.

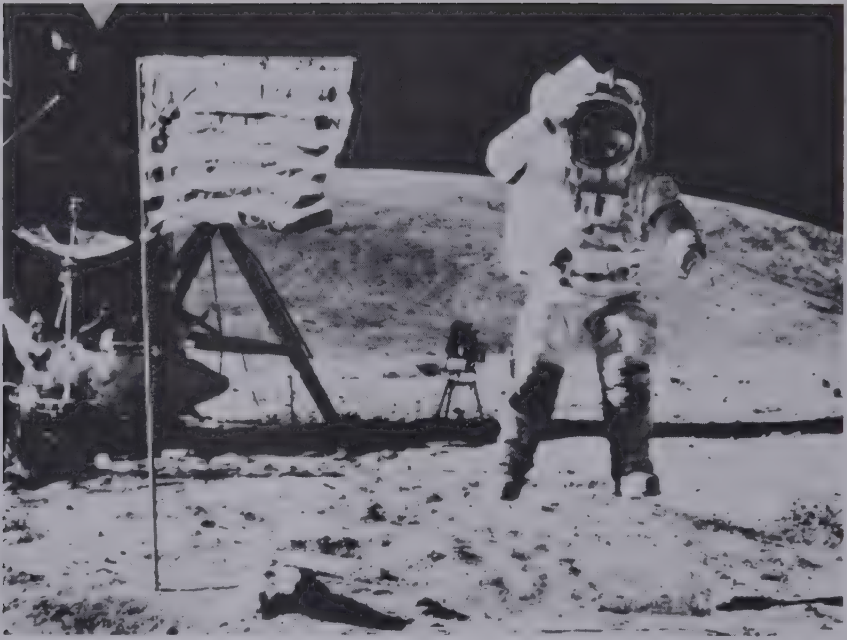
Now you have an instrument that can measure weight. Place an object such as a pen or pencil on the scale. To the nearest unit, how much does it weigh? ★

2-5 An easy way to lose weight

Your weight on earth is how hard the earth pulls you. On the moon, your weight would be how hard the moon pulls you. Astronauts on the moon can jump around easily in their heavy suits (Figure 2-3). If a man and his spacesuit weigh 300 pounds on earth, they will weigh only 50 pounds on the moon. This is because the moon is smaller than the earth. It does not pull as hard.

But even on the moon the earth pulls you a little. So do the sun and planets and stars. So your weight is really a combination of all of these pulls. If you are on the moon, the pull of the moon is the most important. If you are on the earth, the pull of the earth is the most important. If you are in between, in just the right place, you will weigh almost nothing (Figure 2-4). You would weigh a different amount on each planet, as you can see in Figure 2-5.

Figure 2-3 *This heavy space suit was a struggle to put on before blastoff. Why can the astronaut move so easily now?*



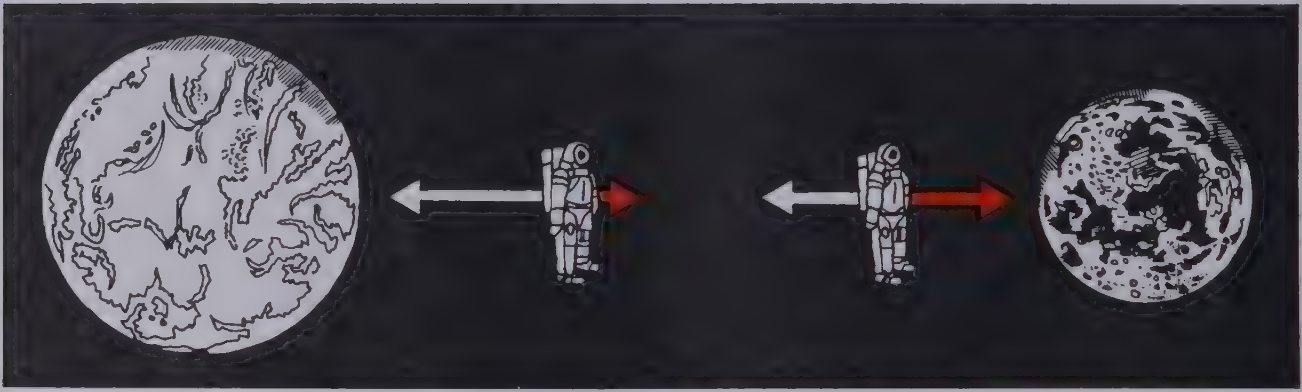


Figure 2-4 *A bigger arrow means a stronger pull. Halfway between moon and Earth will the arrows be equal?*

Figure 2-5 *If you weigh 100 pounds on Earth, here is what you would weigh on some other planets.*

Planet	Weight (pounds)
Venus	90
Earth	100
moon	16
Mars	40
Jupiter	260

Did You Get the Point?

Speed is the distance something goes in a unit of time.

As an object falls, its speed increases.

This happens because the earth pulls on the object with an unbalanced force.

The pull of gravity on the object is its weight.

What Have You Learned?

1. A ball rolls 50 cm in 2 sec. What is the average speed?

2. A plane travels 2000 mi in 4 hr. What is the average speed?

3. Figure 2-6 was taken by flashes equally spaced in time like the picture of the falling ball. Did the golf club move with the same speed all the time? How can you tell?

4. Use the information in Figure 2-5 to find your weight on other planets.

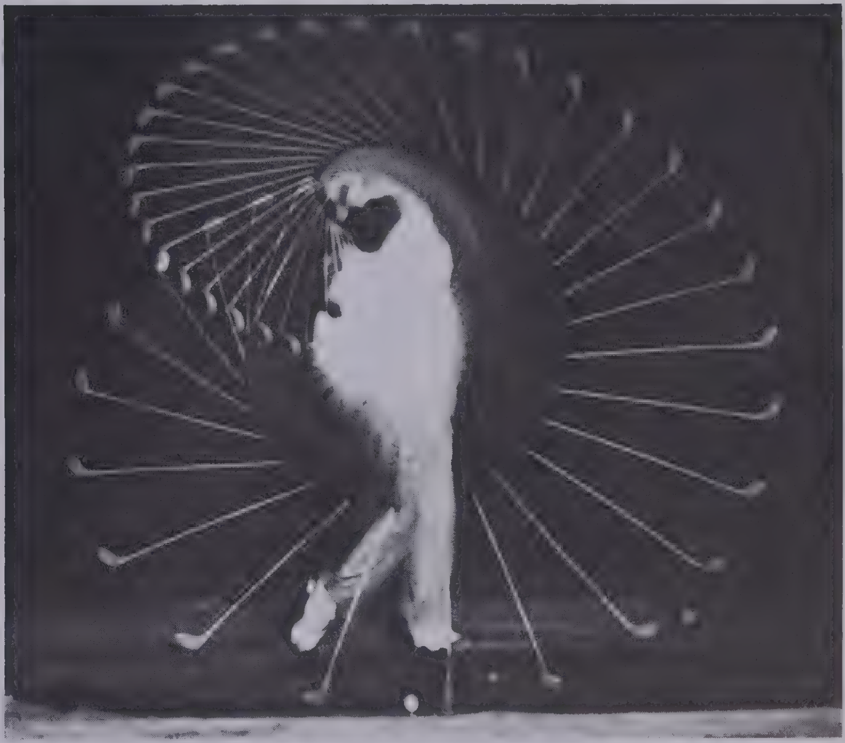


Figure 2-6 *While a light flashed, the camera saw this view of a golf swing.*

Mass and Weight

2-6 Is it easier to lift things on the moon?

★ Your teacher will show you a puzzle box. The plastic balls on top are the kind used for Christmas tree decorations. What can you tell about them without touching them? Now pinch them. Do they seem to be alike?

What do you think about their weight? Are they probably the same or different? Sounds like a silly question, doesn't it? How can you check the weight of something without using a scale? By lifting it, if it isn't too heavy. So try lifting the plastic balls. Discuss what you discover. ★

Pretend that the three plastic balls are in three different places, the earth, the moon, and Jupiter. Which one is which? The rubber bands are substituting for the pull of gravity in the three places. In your model each ball has a different weight.

An astronaut can easily pick up a rock on the moon. Back on earth he will have a harder time, because the rock will weigh six times as much.

The weight of the rock changes when it moves from the moon to the earth. But a lot of other things about the rock do not change. It is still the same color and shape. It still looks the same. An important thing that does not change is its mass. The next activity will help you to understand what the word *mass* means and how you can tell when one thing has more mass than another.

2-7 Testing for mass and weight

People sometimes say that mass is how much matter there is in a thing. This way of talking about mass is a help, but not helpful enough. You need a definition that tells more about how mass behaves. Here it is: **Mass** is measured by how hard it is to make something go faster or slower.

Here is an example. A friend throws a football for you to catch (Figure 2-7). You use a force to stop it. Now he throws you a beach ball at the same speed. It takes less force to stop it. That is because the beach ball has less mass.

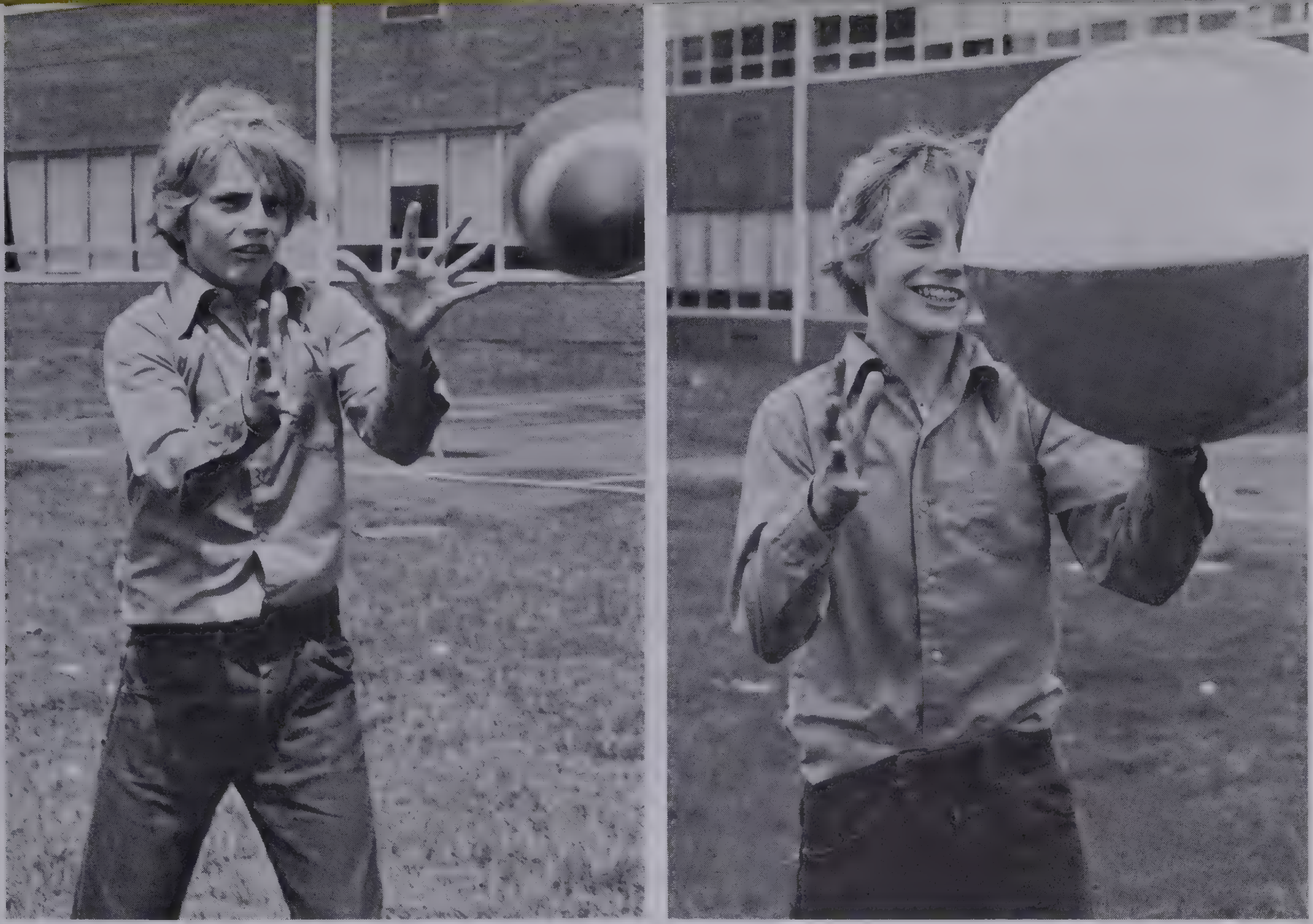


Figure 2-7 *Compare how the boy braces his body to catch the football and the beach ball.*

Materials
3 pails, labels, objects, paper, string, meter stick, ruler

★ Put a label on the bottom of each pail. Later, you will write numbers on the labels. Put a few objects in one pail, a lot in another, and an in-between amount in the third one. Put crumpled paper in the top of each pail so you cannot easily tell which is which.

Now you are ready to test the weight. Remember that weight is how hard the earth is pulling. So to test for weight you lift the pails. Can you tell which has the most weight and which has the least? If not, change how much you put in each pail and test them again. When you are sure which is the lightest, write 1 on the label on the bottom. Mark the in-between pail 2 and the heavy pail 3.

Testing the mass is trickier. You have to change the speed of the pails. You do not want to get mass mixed up with weight, so do not lift the pails.

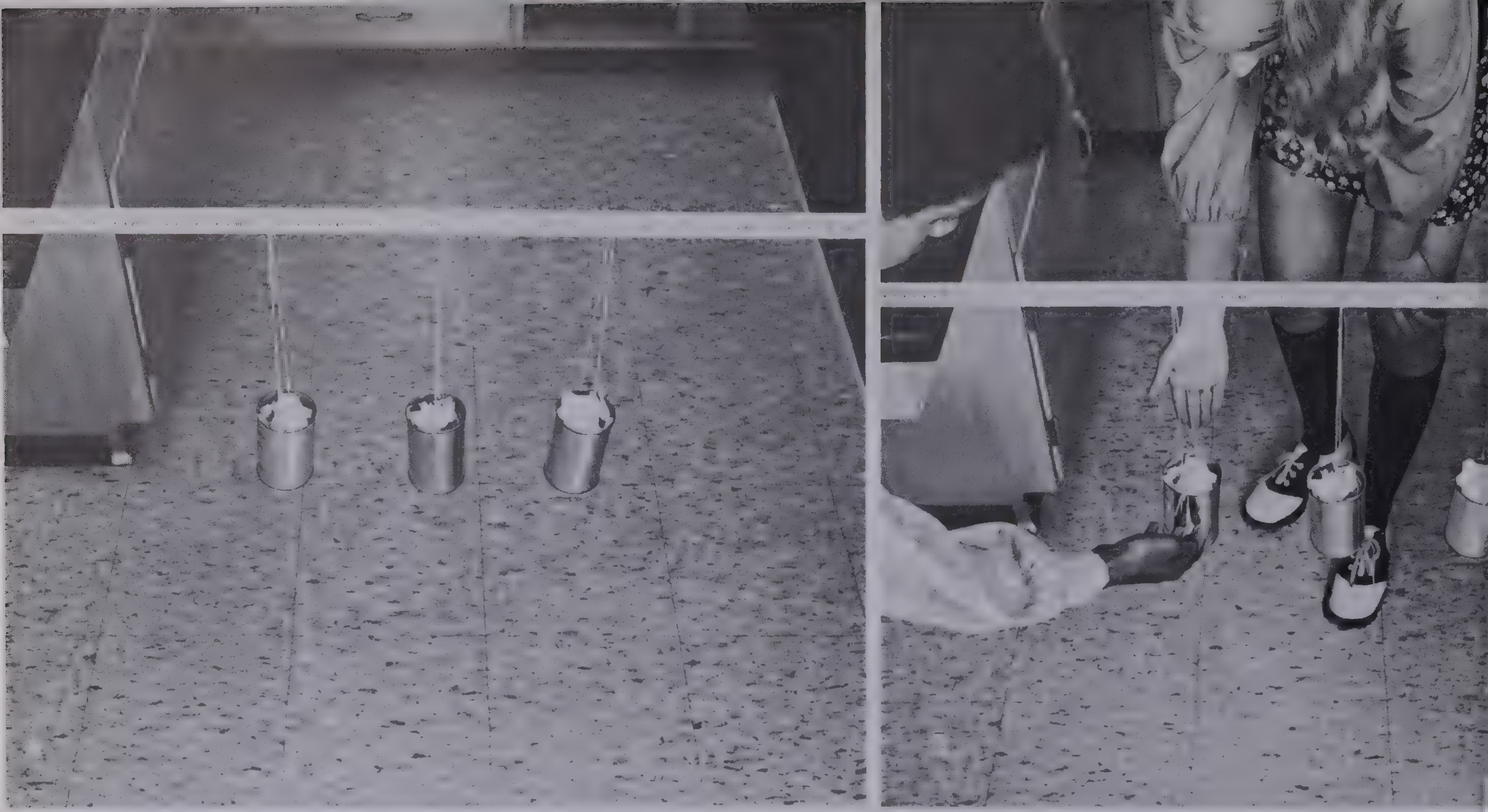


Figure 2-8 *Which can is easiest to push?*

Put a meter stick between two desks and have someone hang the pails on it as in Figure 2-8A. Do not watch while he does it, so you will not know which is which. Be sure the strings are the same length. The strings hold the pails up, so you do not have to worry about their weights, only their masses.

Measure a distance of 10 cm behind a pail and have someone hold his hand there as in Figure 2-8B. Push the pail *horizontally* just enough to make it touch his hand. It should not crash into his hand. Repeat this for each of the other pails. The one you have to push hardest has the most mass.

When you have decided which pail has the most mass and which has the least, look at the labels. Does the pail with the greatest mass have the greatest weight? Write your observations in your notebook.

Now have someone mix up the pails again. Then pull all the pails back the same distance. Let them go. Try to stop each one with your hand. Use the same hand each time. Write your observations in your notebook.

Pull one of the pails back about 10 cm. Let it go. See how hard it is to stop at the bottom of the swing, where it moves fastest. Then pull the same pail back 15 cm. Again try to stop it at the bottom of the swing. Repeat, pulling the pail back farther each time. The farther back you pull it, the faster it is going when you try to stop it. Compare the speed with how hard it is to stop. Write your observation in your notebook. ★

Think about your observations when you answer these questions:

1. A big box of candy weighs more than a pingpong ball. How do their masses compare?
2. A truck has more mass than a sports car. Which is easier to get moving? Why?
3. A baseball and a tennis ball are both coming toward you at 20 m/sec. Which is easier to stop? Why?
4. You are in a place where you weigh nothing. How could you tell the difference between a 200-g ball and a 400-g ball that look exactly alike?

2-8 Newton's law of gravitation

Every mass in the universe attracts every other mass. The force is greater when the masses are closer together. It is also greater when the masses are greater. This is **Newton's law of universal gravitation.** You weigh less on the moon because the moon has less mass than the earth.

However, you do not have to go to the moon to have your weight change. You weigh less if you go up in an airplane because you are farther from the center of the earth. It is the distance to the center that counts. Say you weigh 100 pounds on earth. In a jet plane ten miles high in the sky you might weigh only 99.5 pounds. You even weigh less upstairs than down. You weigh about 99.9997 pounds on the third floor if you weigh 100 pounds on the first.

Where would you weigh least in Figure 2-9? Where would you weigh the most?

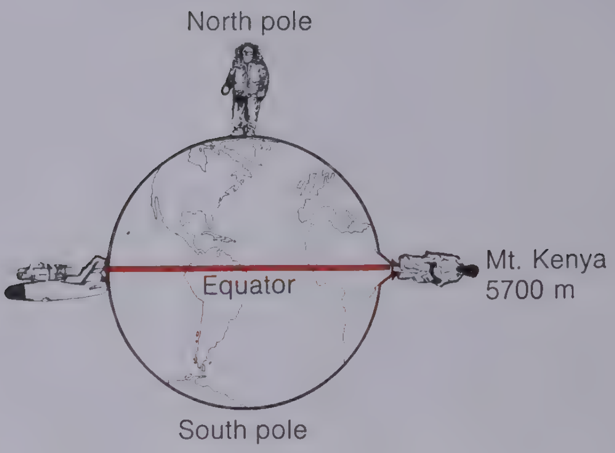


Figure 2-9 *Does it matter where on earth you are when you weigh yourself?*

2-9 You can make a balance to measure mass

Materials
book, pencil, coat hanger, thread, 2 rubber bands, 2 paper cups, cardboard, paper, felt tip pen, paper clips, marbles, rock

If you hang a pencil on your rubber-band scale, you can find how much it weighs. Now imagine that you take the scale and pencil to the moon. The pencil weighs less, so it will not stretch the rubber band as far. But the pencil still has the same mass. In this activity you will make a balance that tells you the mass of the pencil, whether you are on earth or the moon.

★ The pictures in Figure 2-10 show you how to make the balance. When you have it ready, adjust the cups so the balance is level. Make two marks on the white paper to show the level position.

Consider a paper clip to have a mass of one clip. This is your unit of mass. Put the paper clip in one cup of your balance. What happens? Put a second clip in the other cup. Do not remove the first clip. What happens? How much mass does the second clip have?

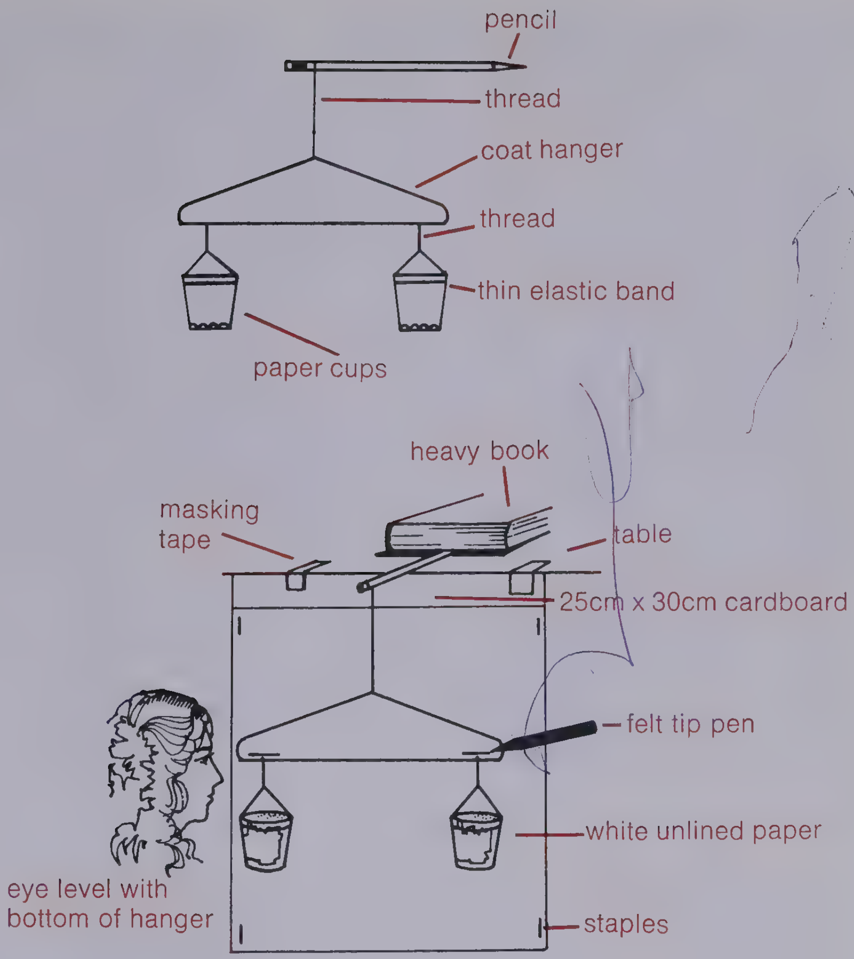


Figure 2-10 *Making a balance to measure mass.*

Remove all the clips from the balance. Put a rock in one cup. Add clips to the other cup until your balance is level again. Find the mass of the rock to the nearest clip. Write the mass in your notebook. ★

Why does this balance measure mass? You found that when the weight of a pail was greater, so was its mass. This balance is like a seesaw. The earth pulls the rock down on one side. It pulls the paper clips down on the other side. When the weights are equal, so are the masses.

What would happen if you took your balance, your rock, and your paper clips to the moon? The moon would not pull as hard on the rock. It also would not pull as hard

LOGGER

The way things fall can be a life-or-death matter to a lumberjack. He has to decide how to cut each tree so that it will fall just where he wants it to go.

Modern lumberjacks may work alone or with a partner. Most logging, however, is done by crews of from three to ten men. Each man has his own task. He may cut down the trees. He may trim off branches. He may haul the logs to the road. Many loggers operate or drive special machinery. Some work with explosives.

Even with modern machines to help, logging is a hard physical job. Loggers work outdoors in all weather. Few loggers live at logging camps anymore. Most commute to the job each morning from their homes in town.

A beginner on a logging crew starts by helping experienced men. As he becomes more skilled, a helper will be given more duties. Schools to train operators of specialized machinery (such as bulldozers and large trucks) are becoming more common.

on the clips. So the balance would still be level. You would still be able to tell the mass of the rock in clips. That is why this kind of balance tells you the mass of an object, not its weight.

2-10 The metric system has special units for mass and weight

Figure 2-11 is a picture of a very special cylinder. The **kilogram** (abbreviation, **kg**) is defined as the mass of this particular cylinder. The **gram** (**g**) is 1/1000 of the mass of this cylinder.

$$1\ \text{g} = \frac{1}{1000}\ \text{kg} \qquad 1\ \text{kg} = 1000\ \text{g}$$

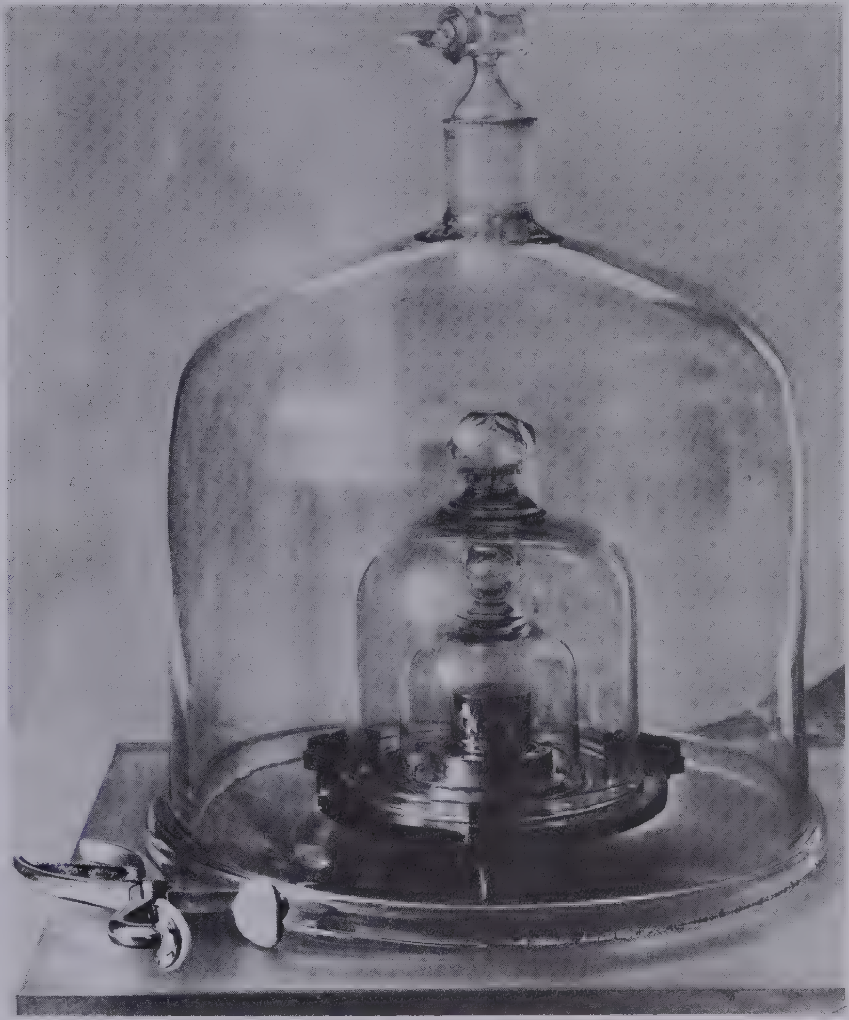


Figure 2-11 *Scientists agreed that this piece of metal has a mass of exactly one kilogram. It is carefully protected and never touched. Even one fingerprint would change its mass.*

In this class you use the meter for length, the kilogram for mass, and the second for time. This system is called the **metric system.**

The unit for force in the metric system is called the **newton** (abbreviation, **N**). See Figure 2-12 for an idea of the size of the newton. On the surface of the earth, a 1-kilogram object weighs almost 10 newtons.

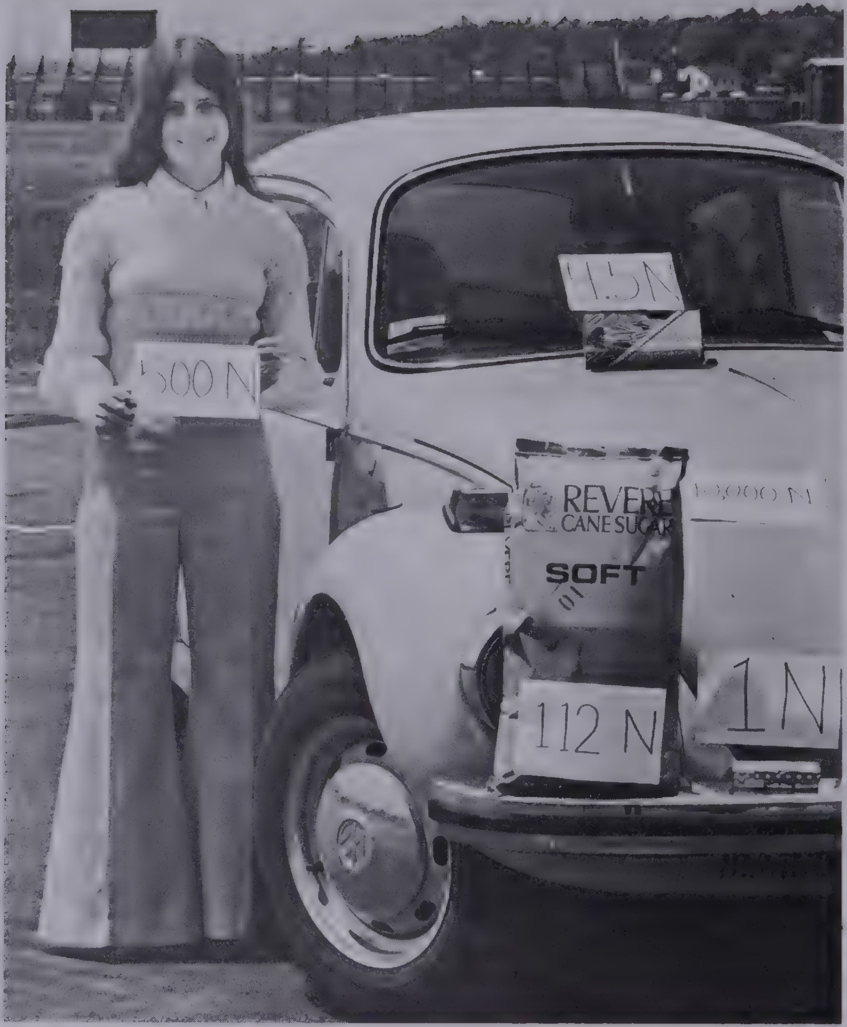


Figure 2-12 *The quarter pound of margarine weighs about 1 newton. The car weighs about 10,000 newtons. What other common objects weigh about 1 newton, 5 newtons, 100 newtons?*

2-11 Do falling objects always speed up?

Materials
2 paper clips, paper

★ Figure 2-13 shows a paper clip fastened to a piece of paper. Pretend this is a person with a parachute. Another clip, just like it, but without the paper, is someone without a parachute. Hold one in each hand and drop them together from the same height. Is there any difference in what they do? Record your observations in your notebook.

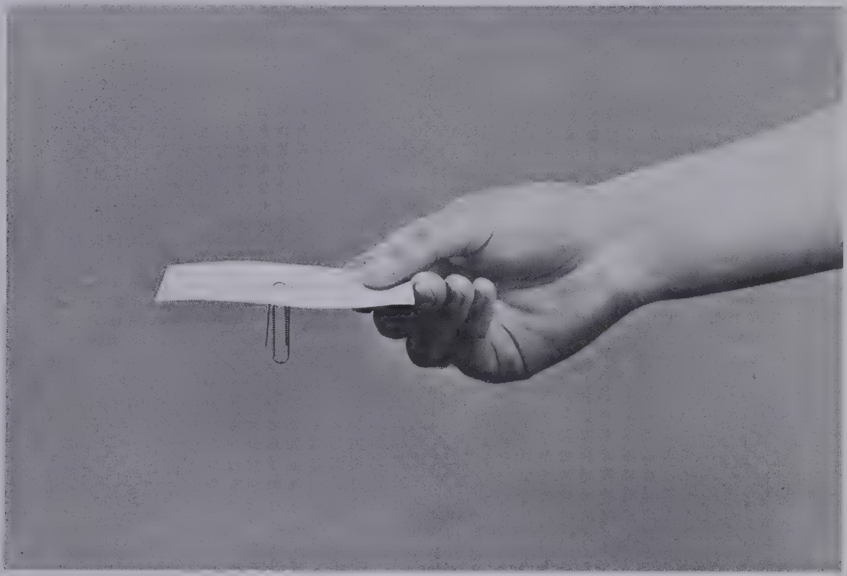


Figure 2-13

How do you interpret what you have seen? Do these observations agree with Newton's first law of motion? Explain. Discuss the observations and interpretations with your classmates. Then write a short interpretation in your notebook. ★

When a man jumps from a plane, he does not open his parachute at first. He falls faster and faster. When he is clear of the plane, he opens the chute. This slows him down. Finally he floats to earth at a steady speed. The steady speed is called his **terminal velocity.** If he jumped without a parachute, the air would still slow him down a little. If he jumped from very high, he might reach a terminal velocity. But he would still be falling much faster than he would with a parachute.

Did You Get The Point?

Mass is measured by how hard it is to make something go faster or slower.

Weight changes when an object moves from place to place. Mass does not.

All masses attract each other.

Air pushing up can balance the weight of a falling object and slow it down.

What Have You Learned?

1. Which is harder to lift, four cases of soft drink on the moon or one case on earth? Why?

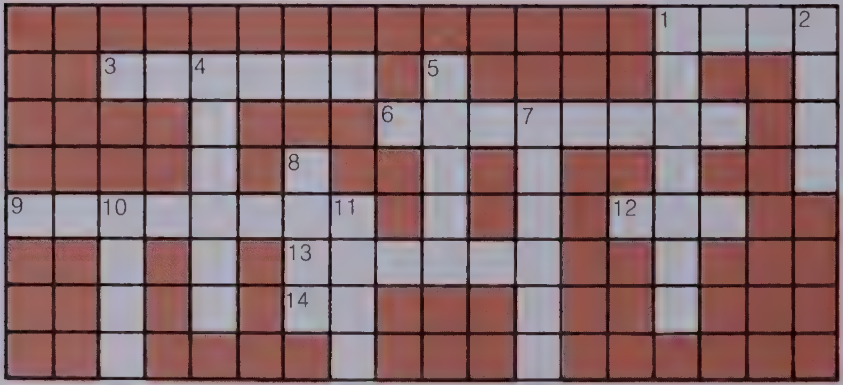
2. Which is harder to push, four cases of soft drink on the moon or one case on earth? Why?

3. If 1 lb is about equal to 4.5 N, what is your weight in N?

4. Why does a parachute jumper slow down when he opens his parachute?

SKULLDUGGERY

1. Solve the crossword puzzle. Do not write in the book.



Across

1. A small unit of mass in the metric system.
3. The man who discovered the law of gravitation.
6. Air resistance causes a parachute jumper to fall at a ____ velocity.

9. 1000 grams.
12. On the earth you weigh ____ times as much as on the moon.
13. If your speed is great, you get somewhere ____ than if your speed is low.
14. A person on Jupiter would weigh ____ much because Jupiter has a very large mass.

Down

1. You have weight because of the force of ____.
2. The earth has ____ mass than the moon.
4. Your ____ is greater at the bottom of a mountain than on top.
5. A bug that crawls 14 cm in 2 sec has a speed of ____ cm/sec.
7. The newton is a unit of force in the ____ system.
8. Your ____ is the same on the moon as on earth.
10. The earth has ____ mass than Jupiter.
11. You could jump higher on the ____ than on earth.

2. Suppose you buy a pound of cookies in Atlanta. You take them to Denver without eating any of them. Will you still have a pound of cookies in Denver? Is it fair to sell things by weight? Explain.

FOR FURTHER READING

Bendick, Jeanne. *Measuring*. New York: Franklin Watts, Inc., 1971. What measurement is, how it is used, and the need for standard units.

Valens, Evans G., and Bernice Abbott. *The Attractive Universe: Gravity and the Shape of Space*. New York: World Publishing Company, 1969. Explains gravity by illustrated analyses of falling objects and paths of planets.

WHAT'S NEXT?

A spaceship is on the launch pad at Cape Kennedy. The countdown is going on—10 – 9 – 8 – 7 – 6 – 5 – 4 – 3 – 2 – 1 – 0—BLASTOFF.

The ship rises straight up slowly, then faster and faster. Flames rush out behind. Soon the people watching cannot see it any more. It turns and coasts around the earth. All is going well. It turns again and starts for the moon.

Unbalanced forces make these things happen. In the next chapter you will learn how.

Chapter 3

How Unbalanced Forces Change Motion

"Hey, I want to ride on that," said Jennifer. She and her friends were at the carnival.

"Me too," said Marie.

"It looks scary," said Marie's brother Joe. "Do they really take the floor out from under you?"

"Yes," said the ticket seller, "But you can't fall."

"Far out," said Marie. "We were talking about it in science class. You get going and Newton's first law keeps you pushed against the wall."

"Who's Newton?" asked Joe.

"You know, the man who got hit by the apple and invented gravity," said Jen. She didn't pay as much attention in class as Marie.

"Not exactly," said Marie. "Anyway, it's really friction that keeps you up. The harder you push against the wall, the more the friction. The faster you go, the more you push."

"I thought it was how hard the wall pushed you," said Jen. She did pay attention some of the time.

"Same thing," said Marie, "or almost."

"Let's go," said Joe.

So there they are in the picture. The floor is gone and they are stuck against the wall. No one is falling. Magic? Not really. The man who invented this ride was only using his head and some of the laws of nature.

Unbalanced Forces Change Motion

3-1 Whirling balls

Figure 3-1 shows a ball whirling at the end of a string. A picture was taken every tenth of a second. Was the speed of the ball always the same? How do you know?

In Chapter 1 you learned about Newton's first law of motion. Part of that law says: If an object is moving, it will keep on moving at the same speed in a straight line unless an unbalanced force is applied to it. This ball is not moving in a straight line. How do you explain the way the ball is moving?

The student in Figure 3-2 is making the ball move in a circle on the top of the table. Answer the question in the caption. Your answer is your hypothesis. Record the hypothesis in your notebook.

Figure 3-1 *Each time the light flashes, the whirling ball is in a different place.*

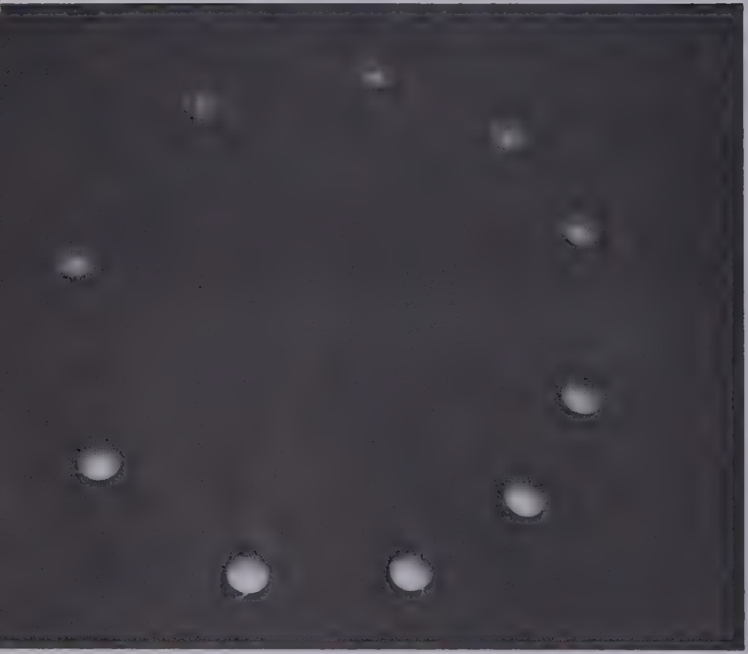
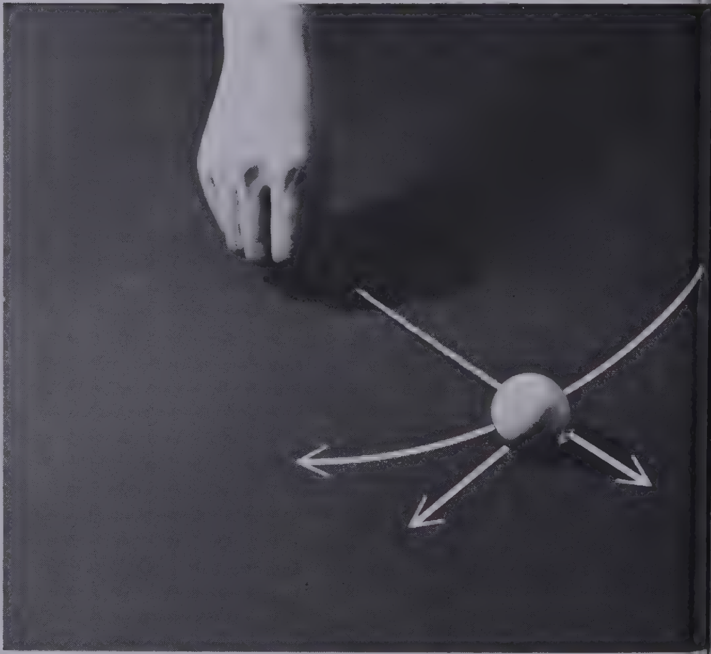


Figure 3-2 *If the student lets go of the string right now, which way will the ball go?*



Materials
ball, string

★ Now whirl the ball yourself. Do it on the floor or the table top, not in the air. See what happens when you let go of the string. Do this several times to be sure. Then copy the pictures in Figure 3-3 in your notebook. With an arrow show what happens each time when you let go of the string. Does your observation agree with your hypothesis?

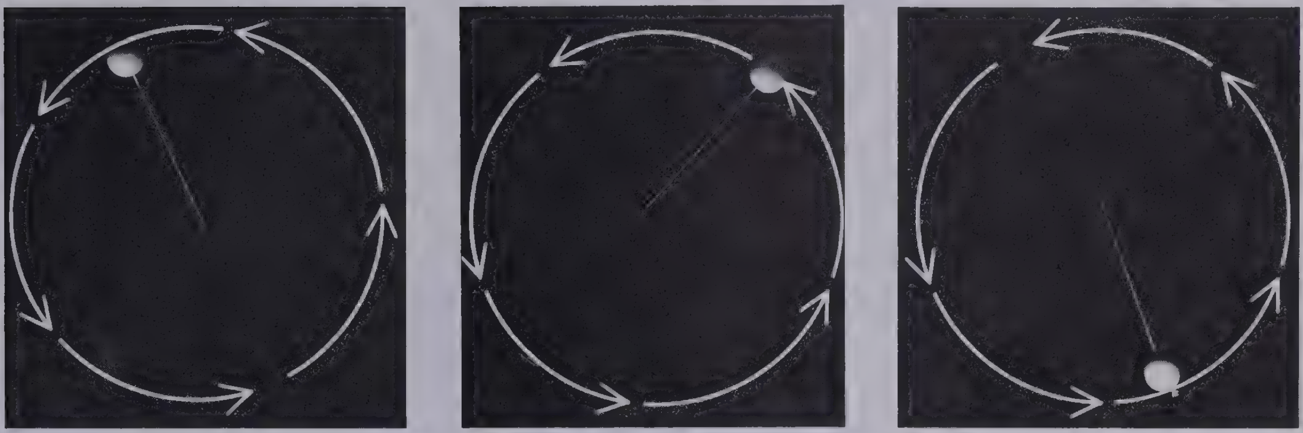


Figure 3-3 *Which way will the ball go?*

Your observations need interpretations. Here are questions to help you. Think about them, without writing answers. Then discuss them with the rest of the class.

1. According to Newton's first law, what does a moving object do when there is no unbalanced force?
2. Did your ball do this when you held the string? Did it do it when you let go?
3. Which time did the ball move without an unbalanced force? How do you know?
4. When was there an unbalanced force? What did it do to the ball?
5. How was the unbalanced force applied to the ball? Was it a push or a pull? What was its direction?
6. An unbalanced force can change the motion of an object in two ways. What are they?

After you have discussed these questions, write your interpretation in your notebook. It should explain (1) why the ball went in a circle at first; (2) why it did something else when you let the string go; (3) the two kinds of change in motion that can be caused by an unbalanced force. Be sure to write complete sentences. ★

3-2 Experiments with unbalanced forces

Materials
soft object, string

★ 1. Take several steps in a straight line. Then make a sharp turn to your left. How do you do it? Notice the force on your right foot when you are going straight. Then notice the force on that foot when you turn. How are the forces different? What pushes you around the curve?

2. Tie something soft, like a pillow or a stuffed toy, to the end of a string. Now whirl it as in Figure 3-4. Be sure you have plenty of room to swing. You need something soft so it cannot hurt anything. Notice how hard you pull when it is near the ground. Compare it with how hard you pull when it is above your head. Why are the pulls different? ★

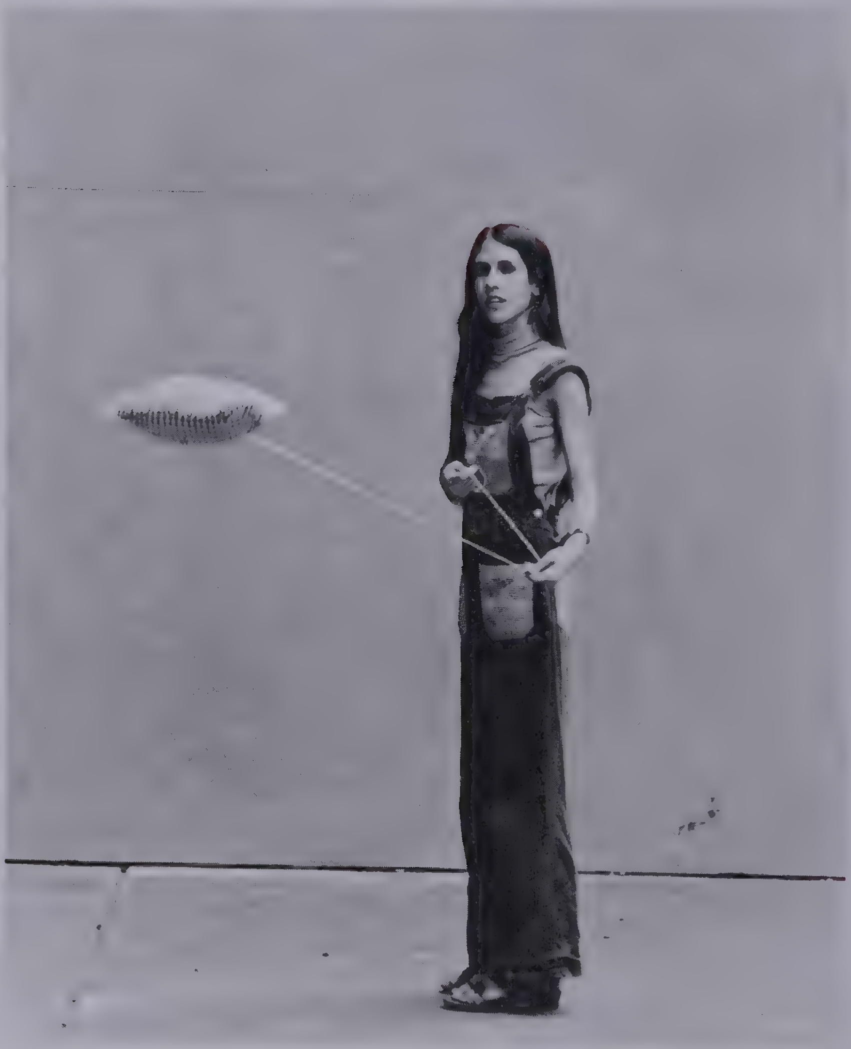
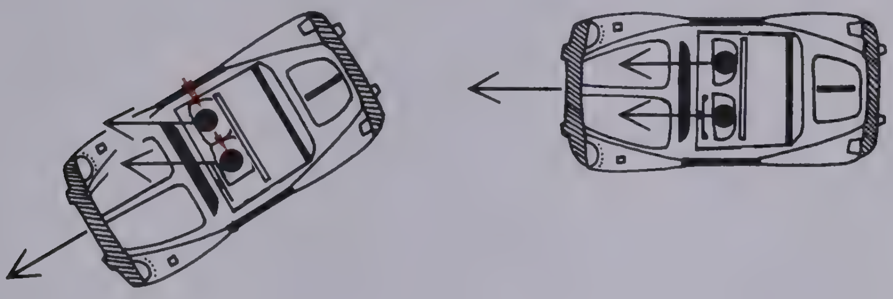


Figure 3-4 *Try this yourself. When do you have to pull hardest?*

Figures 3-5 and 3-6 show some other examples of unbalanced forces. They may help you to explain what happened in your two short experiments.



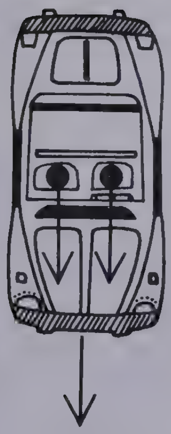
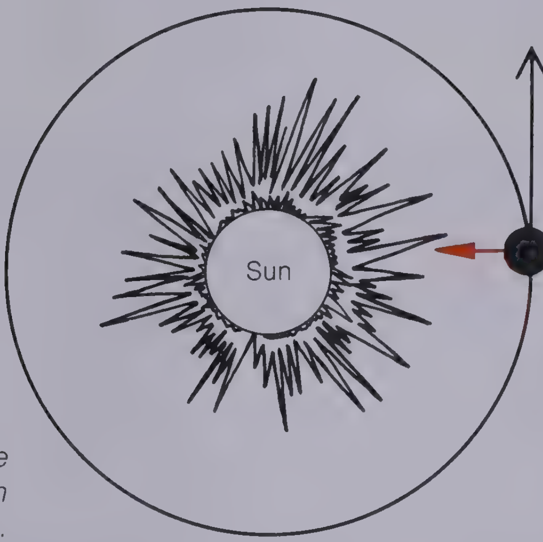


Figure 3-5 *How a car pushes you around a corner.*



The earth would go this way if the sun did not pull it.

But the force of gravity of the sun pulls the earth this way. The force is unbalanced, so the earth changes direction.

This is just like you and the ball you whirled. There is no string to hold the earth. But there is an invisible force of gravity. The earth cannot escape.

Figure 3-6 *Gravity is the "string" that keeps the earth from flying off into space.*

Did You Get the Point?

An unbalanced force sometimes changes the speed of an object.

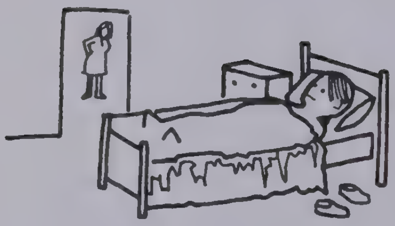
An unbalanced force sometimes changes the direction of a moving object.

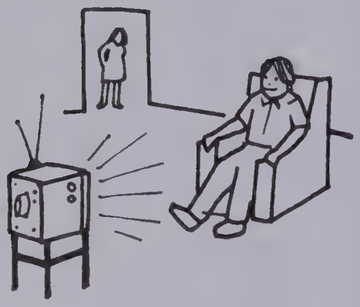
Sometimes an unbalanced force does both of these things at once.

What Have You Learned?

Soon after a spaceship has blasted off for the moon, its engines are turned off. After that the ship coasts. While it is coasting away from the earth it slows down at first. Then, when it comes closer to the moon, it speeds up. Use Newton's law to explain this.

How Easy Is It to Change Motion?





3-3 Matter is lazy

"Jimmy. Time to get up."

But Jimmy does not move. He pretends he has not heard.

In the afternoon, Jimmy is playing ball with his friends in the street.

"Jimmy," his mother calls. "Suppertime."

But Jimmy is up at bat. Again he pretends he has not heard.

Later he is watching television.

"Time to help with the dishes, Jimmy."

But again Jimmy pretends he does not hear. He slumps down in his chair.

"That lazy boy! He never wants to get up in the morning, and he can't lift a hand to help," says his mother.

Jimmy likes to keep on with whatever he is doing, whether it is sleeping, playing a ball game, or watching TV.

The pails in the investigation of mass and weight act a little like Jimmy. They resist being started and they resist being stopped. Of course, they cannot think about what they are doing, as Jimmy can. It is a law of nature that every mass resists changes in its motion.

A hanging pail does not start to move unless an unbalanced force acts on it. The greater the mass in the pail, the harder it is to start or stop it.

This kind of resistance is always there. If you push a rock, it resists you. Even if the weight is zero (out in space somewhere) this is true because the rock still has mass. If the rock is not moving, you have to push to start it. If it is moving, you have to push to stop it. Every mass has resistance to change in motion. The greater the mass, the greater its resistance.

3-4 Is it easier to push an elephant or a fly?

Silly question? It is easier to push the fly, of course.

But wait a minute. What do you mean by easier? Suppose you pushed them both equally hard. They'd both be just as easy then. Maybe what happened would be different, but that's not what the question is about.

Let's not fool around with elephants, though. They might get mad and step on you. Take something easier, a car and a child's wagon. Not as exciting, but safer. The car sits on a level street with the brakes off. Probably you can push it hard enough to start it moving. Now think about pushing the wagon. See Figure 3-7 and answer the questions.

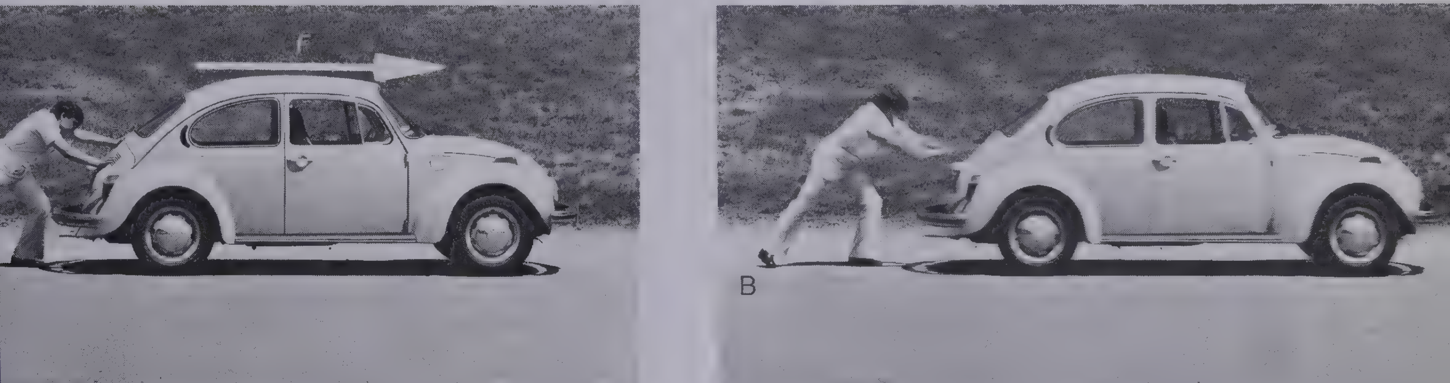


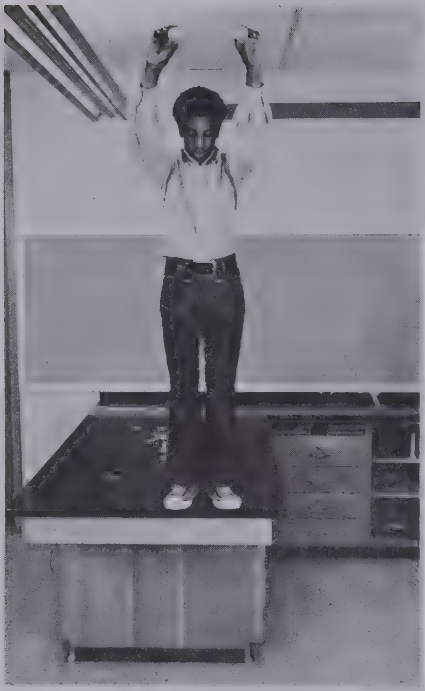
Figure 3-7 *(A) You push the car with an unbalanced force. (B) It starts to move slowly. (C) What happens if you push the wagon for the same length of time with the same unbalanced force you used on the car? If you want the wagon to go at the same speed as the car, should you use the same force?*

Newton thought about questions like this. He decided his first law did not tell enough. **Newton's second law of motion** tells what happens when there is an unbalanced force: If an unbalanced force acts on an object, it changes the speed or direction of the motion. The greater the mass of the object, the greater the force needed to change the motion a certain amount. The faster the speed or direction changes, the greater the force that is needed.

3-5 The strange behavior of falling objects

★ Take two balls of the same size, but with different weights. Weigh them. Now stand as high as possible (Figure 3-8), holding one ball in each hand. What will happen when you drop them? Make a hypothesis.

Figure 3-8



Drop both balls at the same time. Which hits the floor first? You can tell best by the sound. Only one person in the class should do this at a time. Then everyone can listen better. What do you discover? Use what you have learned in this chapter to explain what happens. These questions will help you.

Why did the balls fall?

Which ball was pulled by a larger force?

Which ball has more resistance?

Now stand up on the desk again. This time have the heavier ball in one hand and a sheet of paper in the other. Guess what will happen when you drop them. Try it. What happens?

Before you try to explain what happened, try it again differently. Crumple the paper into a ball about the same size as the heavy ball. Guess what will happen. What happens when you drop them? Now explain what you saw. ★

Did You Get the Point?

All masses resist change in motion.

An unbalanced force changes the speed or direction of motion of a mass.

The greater the force, the faster the change in speed or direction.

The greater the mass, the greater the force that is needed for a particular change.

Air resistance can change the unbalanced force on a falling object.

What Have You Learned?

1. You push a marble and a bowling ball with the same force. What happens? Why?

2. You catch a fast ball with your bare hand. Your hand moves back while you make the catch. Later you catch again. The ball is just as fast. But this time you try not to let your hand move back. Why does it hurt more the second time?

3. Which falls faster, a leaf or a big drop of rain? Why?

Space Travel Uses the Laws of Motion

3-6 A balloon can be a rocket

Materials
balloon, flour or other fine powder

★ Blow up a balloon. Hold the opening by pinching it between your fingers (Figure 3-9). Hold it high and let it go. What happens?

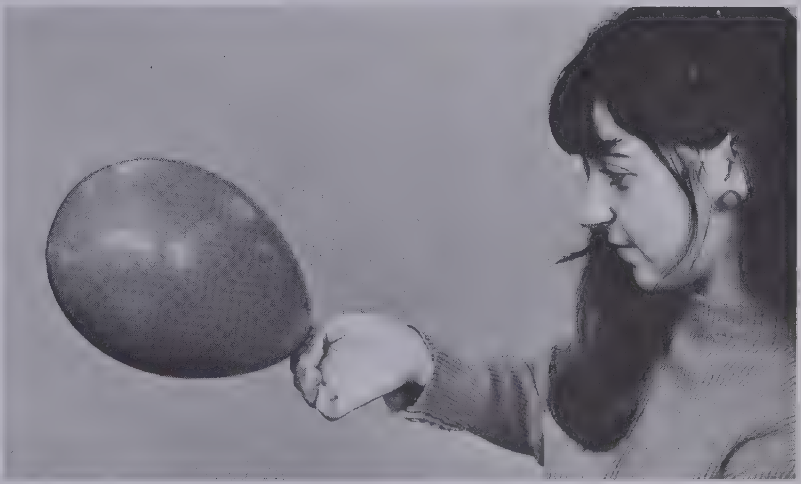


Figure 3-9

Put a pinch of flour or powder in the balloon before you blow it up. Let it go again. What do you see? ★

Something must have pushed the balloon to make it do what it did. What did the pushing? Did anything else get pushed? How do you know? What pushed it?

The balloon is a rocket. It moves for exactly the same reason that great moon rockets move during blastoff.

3-7 Many things behave like rockets

Materials
dynamics cart

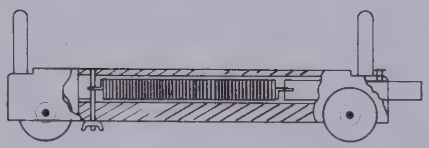
★ Your cart (Figure 3-10) has a spring inside it, behind the long rod. Push the rod in as far as it will go. This squeezes the spring. Push the rod up behind the plate. Put the cart down on the floor or table. Tap sharply straight down on the trigger. What happens?

Fasten the rod in place again. Put the cart against the wall or a heavy box on the table. The rubber cork in the end of the rod should touch the wall. Tap the trigger. What happens?

Did the cart move both times? It cannot start to move unless something pushes it. When the cart was touching the wall, did the rod push on the wall? What pushed on the cart?

Squeeze the spring on the cart again. Put the cart on the floor or table. Put another cart beside it (Figure 3-11). Tap the trigger. What happens? Why? The two carts act much like the balloon. Explain. ★

Figure 3-10 *How a dynamics cart works.*



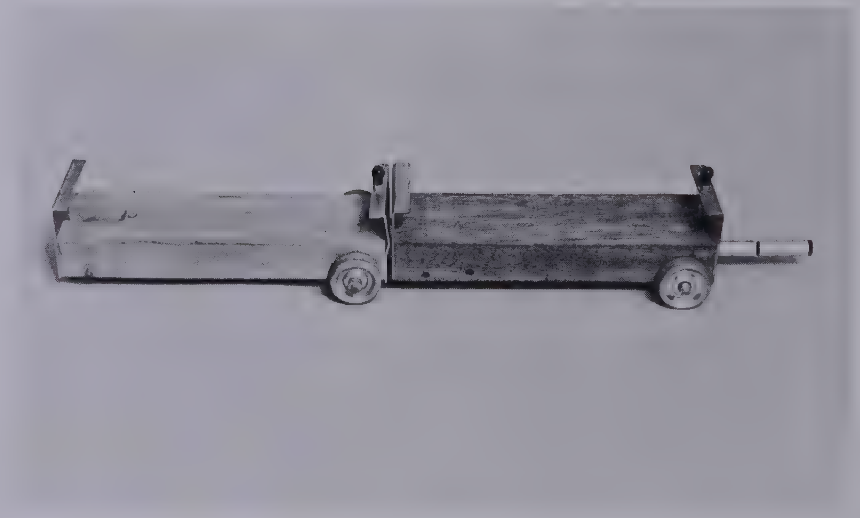


Figure 3-11

3-8 You can't hit a man who doesn't hit back

Lean against the back of your chair. You can feel the chair pushing on your shoulders. Every time you push on something, it pushes back. If you slap a friend on the back, you feel his back pushing your hand. The only way your friend can keep from pushing you is by running away. Then you can't touch him. If you pull on a rope tied to a post, the rope pulls back. The pulls or pushes are always equal.

Newton's third law of motion is a way of saying what you have been observing: For every push, there is an equal push back. For every pull, there is an equal pull back.

The two pulls or pushes are equal. They are in opposite directions. But they do not cancel each other out because they are pushing or pulling on different things. Often they cause motion. See Figure 3-12.

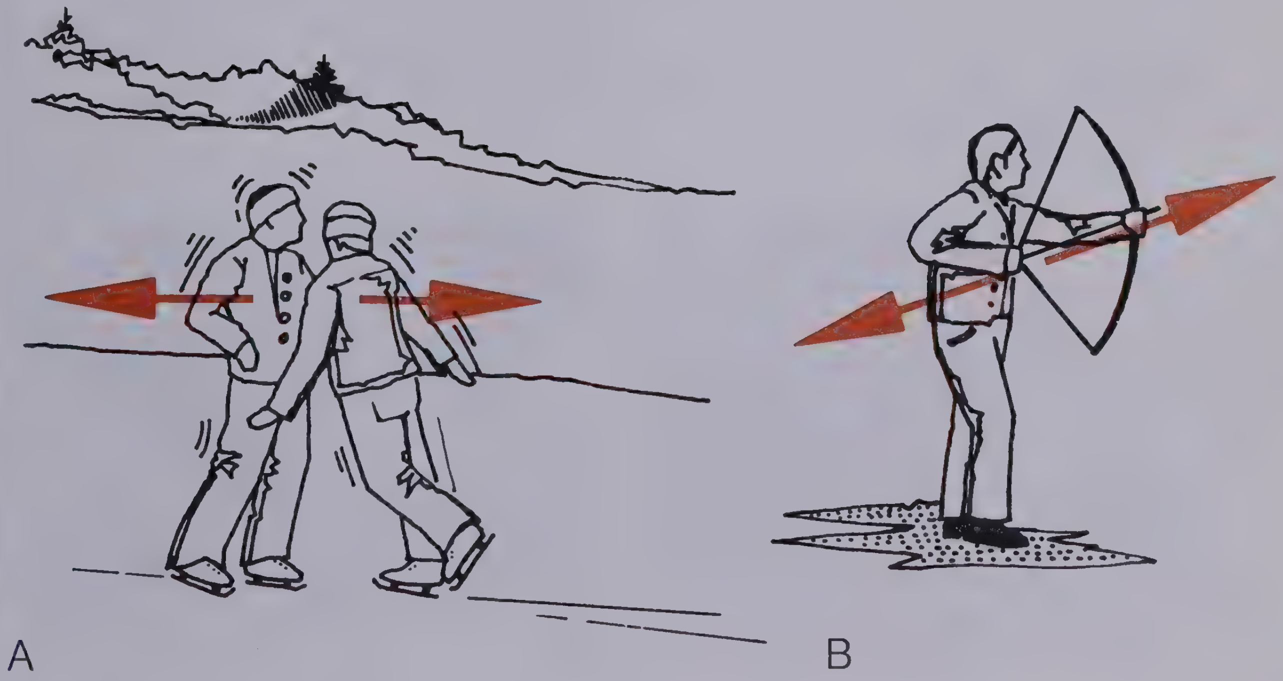


Figure 3-12 *How does an unbalanced force cause motion in each picture?*

3-9 You couldn't get along without Newton's laws

If you ask someone how he can swim, he may tell you that he pushes against the water. This is true, but it is only half the story. When he pushes against the water, he makes the water move. But the water pushes back (Newton's third law) and that is what makes the swimmer move (Figure 3-13).

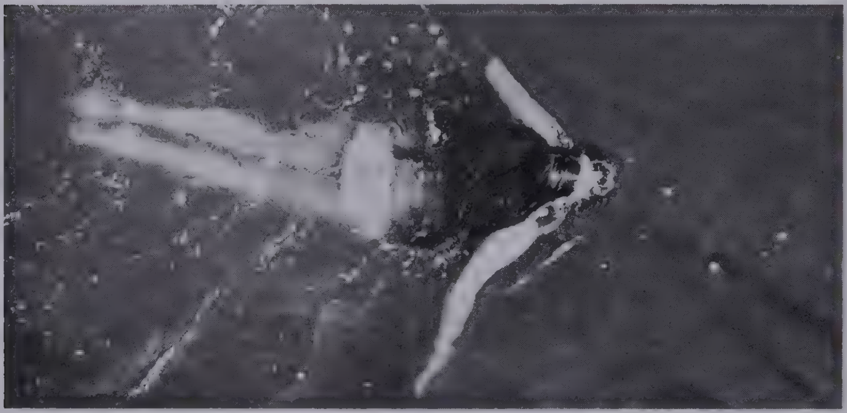


Figure 3-13 *What forces make the swimmer move forward?*

When you walk, you push against the ground. The ground pushes in the opposite direction on you. This is what moves you forward (Figure 3-14). The forces between you and the ground are called forces of friction. What happens when you try to walk on ice with slippery shoes? Why?

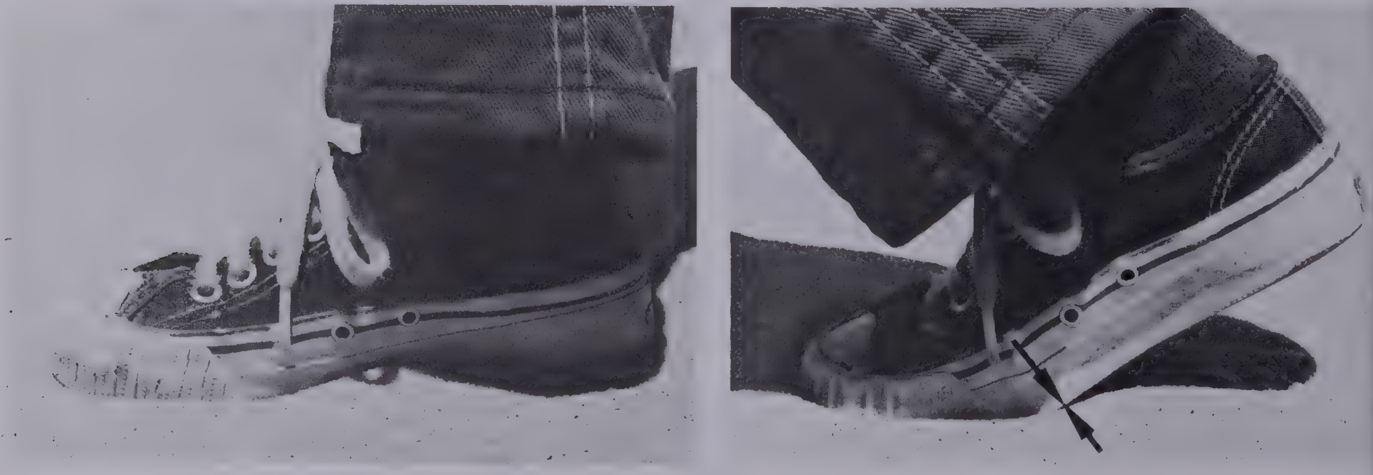


Figure 3-14 *Which pushes harder when you walk, you or the ground?*

The whirler at the carnival uses all three of Newton's laws of motion. It uses friction too. To see how friction helps, try this experiment. Push your notebook against the wall hard enough so it does not slip. Now don't push quite so hard. The book starts to slip down the wall. See Figure 3-15 for an explanation of how friction holds the book up.

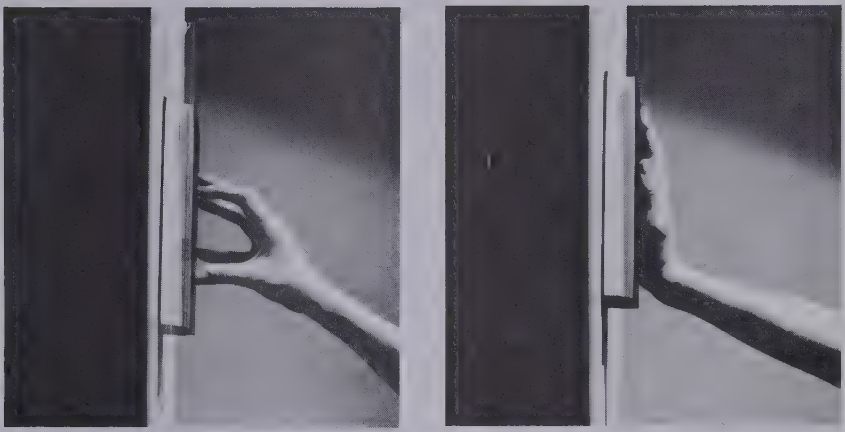


Figure 3-15 *When you don't push very hard (left), there isn't enough friction to keep the book from slipping. When you push harder (right), the friction is greater. It can become enough to balance the weight and hold the book up.*

Notice that the force of friction always opposes the force that is making something move. If the friction is big enough, it can stop the motion. See Figure 3-16 for a story about Newton's laws and the carnival whirler.

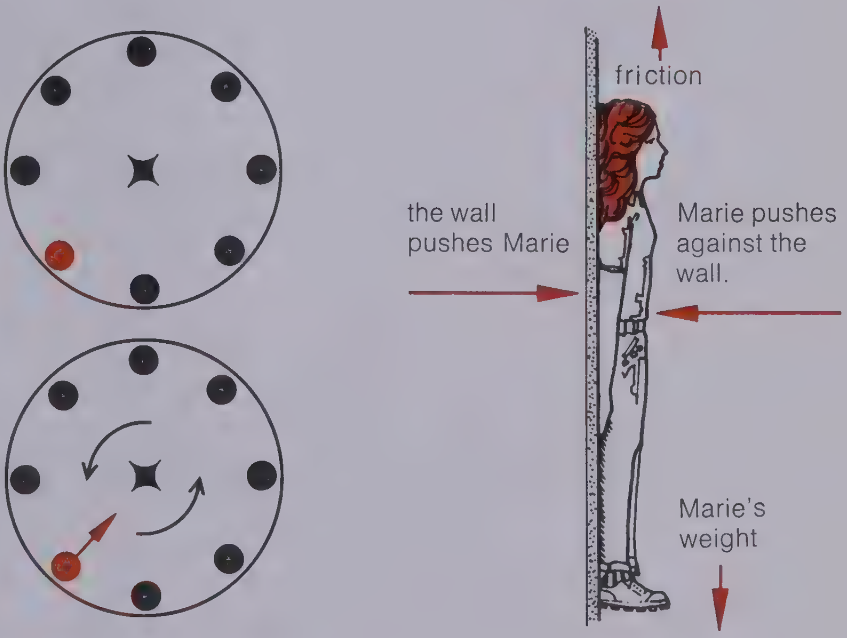


Figure 3-16 *(top left) Here are the people in the whirler. You only see the tops of their heads because you are looking down at them. Marie is the red-head. (bottom left) The whirler starts to turn. Marie moves too because of the friction of her feet on the floor. But she starts to go in a straight line (Newton's first law). She bumps into the wall. The wall pushes her (Newton's third law). This is an unbalanced force pushing Marie. It changes her direction (Newton's second law) and makes her go in a circle. (right) The whirler goes faster. Marie pushes harder against the wall. When the floor goes out from under her feet, the friction is enough to hold her up.*

Did You Get the Point?

Every time a force pushes or pulls on an object, the object pushes or pulls back with an equal force.

The force of friction always opposes the force that is making something move.

What Have You Learned?

1. What would happen if you tried to walk on ice that was so slippery that there was no friction? How could you get off a pond of frictionless ice? (Hint: Think about the balloon experiment.)

2. What makes an Apollo spacecraft lift off from the launch pad? Why does it go faster and faster as it rises?

3. Partway to the moon, one of the astronauts steps out of the spaceship. If the ship is going 10,000 miles per hour, will the astronaut be left behind if he does not tie himself to the ship?

4. What happens if he pushes one hand against the spaceship when he is outside? Why does he tie himself to the ship?

5. When the spacecraft gets near the moon, how can it slow down?

6. While the ship is coasting, the men feel weightless. But most of the time they really do have weight. Why do they feel weightless? Before you answer, ask yourself how you feel your own weight.

7. Imagine a way to make you feel that you have weight in a coasting spaceship.

SKULLDUGGERY

The man in Figure 3-17 is wearing a rocket belt. He has tanks of gas on his back and a tank where the gases can mix and burn. Then hot gases come shooting out of the nozzles. He can turn the nozzles any way he wants. People using these belts have jumped 100 feet in the air and have gone forward as much as 300 yards. Imagine that you have a belt like this and tell what you would like to do with it.

In your story tell how you should hold the nozzles to make yourself go straight up, how you would go forward, how you would make turns, and how you would keep from hitting the ground too hard when you come down.

FOR FURTHER READING

Froman, Robert. *Baseball-istics: Basic Physics of Baseball.* New York: G. P. Putnam's Sons, 1967. Physics of motion in understandable terms.

Legunn, Joel. *Motion.* New York: Creative Education Press, 1971. Introduction to the science of mechanics including speed, velocity, force, momentum, and Newton's laws of motion.

Posin, Daniel Q. *Exploring and Understanding Rockets and Satellites.* Westchester, Ill.: Benefic Press, 1967. Discusses history and present day developments.

WHAT'S NEXT?

Forces can get a man to the moon and back—if he knows how to use them. Forces can make life easier on earth—if you know how to use them. In the next chapter you will learn how to make forces help you.

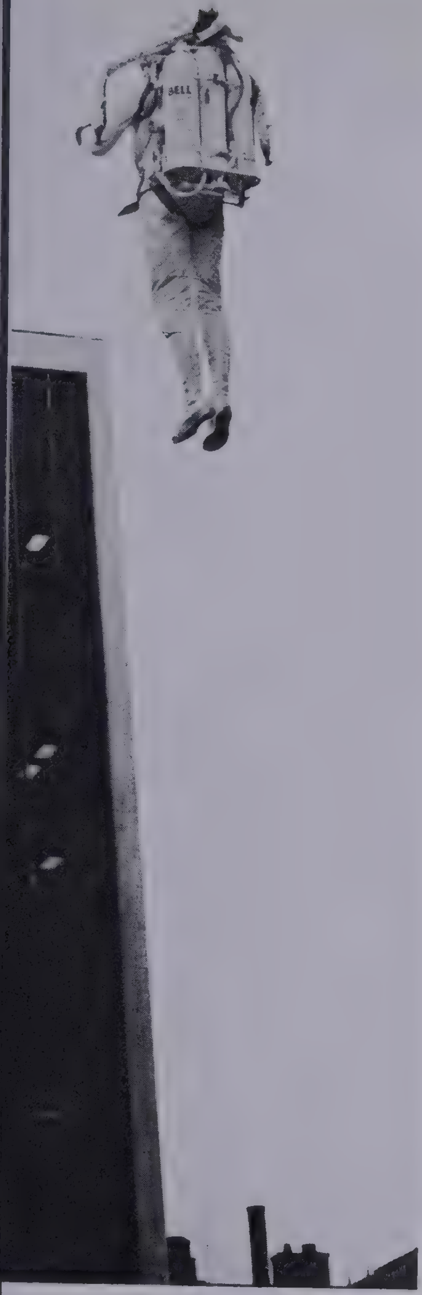


Figure 3-17 *How would you use a rocket belt?*

Unit Two

Making Forces Useful

AGILE
36

Chapter 4

Easy Ways to Do a Job

''Hey, Bill, what's the matter? Can't you push that box?'' asked Theresa.

''Sure I can, but it's pretty heavy. Give me a hand.''

As they pushed, the box moved very slowly.

''There must be an easier way,'' suggested Janet.

''Too much friction,'' said Pete.

''Any ideas?'' asked Bill.

''Yeah. See that stuff on the table? Maybe if we put something under the box it would help.''

''Maybe it would be easier if we pull it,'' said Janet.

''I know the best way,'' said Carlos.

''If you're so smart, you can do it.'' Bill and Theresa stopped pushing.

Friction

4-1 Friction is an important force

Materials
heavy box, other objects

★ There are many ways to make it easier to move a heavy box. Each team in your class has a box like the one in the picture. See how many ways you can invent to do the job more easily. You will find things around the room that you can use. See which team can find the most different ways. Which way seems best? ★

The boxes were hard to move because of friction between the box and the floor. **Friction** is a force that opposes slipping. When a car is moving, it slips past the air. There is friction between the car and air. A moving boat slips past the water. There is friction with the water.

Sometimes there is friction when nothing is moving. The box in Figure 4-1 will not slide down the board. Friction between the box and the board will hold it back. What would happen to the box if there were no friction at all? It would slide down, but what would happen after that?

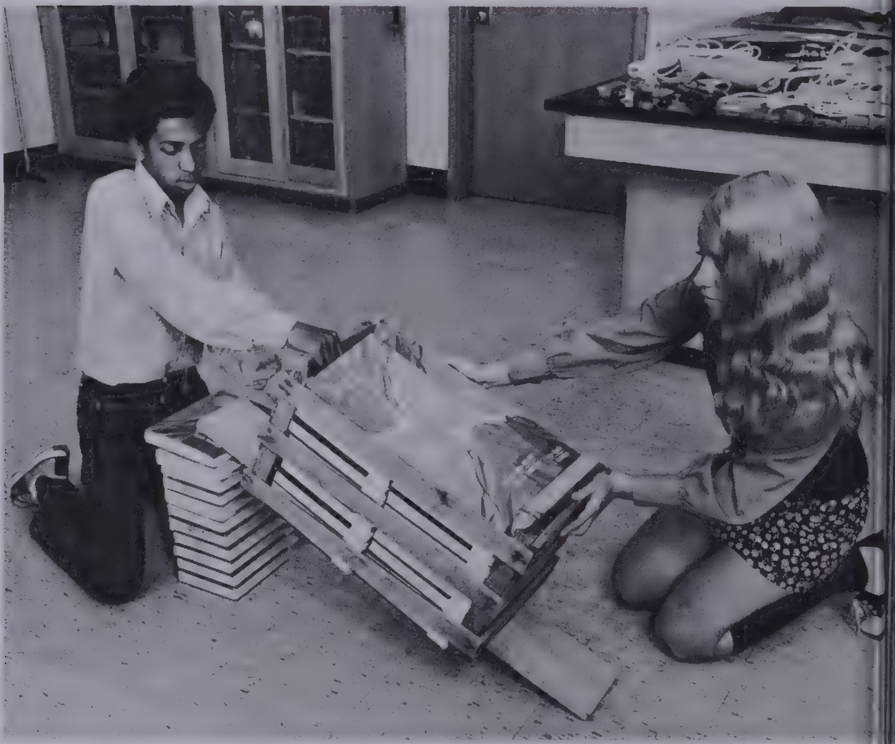


Figure 4-1 *What force will keep the box from sliding?*

If you try to push a heavy piece of furniture, you wish the friction would go away. But friction is good, too. You need it when you walk. On slippery ice you fall down. Friction in car brakes stops the wheels. Friction between the tires and the road makes the car stop. If there is not enough friction between the tires and the road surface, the car skids.

4-2 Measuring friction

The force of friction can be measured with a spring scale (Figure 4-2). A spring scale is like the rubber-band scale you made in Chapter 2. You used that scale to weigh light things. You need a stronger one to measure the force to pull your box.

In the metric system, force is measured in newtons. However, your scale is probably marked in kilograms. When the pointer of the scale is at the 1-kilogram mark, the force is equal to the gravitational pull on a 1-kilogram mass at the surface of the earth. This is almost 10 newtons. So when you record the force, multiply by 10 and call it newtons.

Materials
heavy box, spring scale, string, other objects

★ Start by measuring the force of friction, as in Figure 4-2. Notice the measurement when the box starts to move.

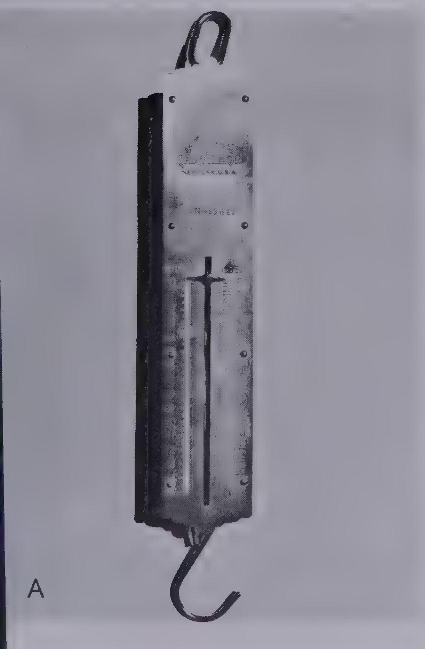
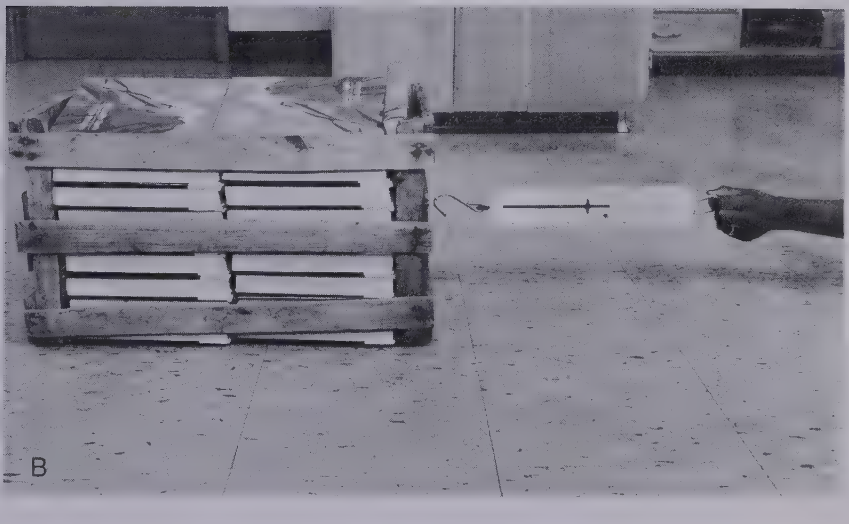


Figure 4-2 (*A*) *A spring scale.* (*B*) *To measure the force of friction, pull at a steady speed . Keep the spring scale parallel to the floor.*



What is the measurement later, when the box is moving at a steady speed? Why is there a difference? Use the force when there is a steady speed for your measurement of friction.

Each team will work on one of the problems listed below. Set up a table in your notebook to write the measurements in. Later you will also write down measurements from other teams.

Team 1: Measure the force of friction when the box is (a) on the floor, (b) on newspaper, (c) on a piece of rug. Then try fastening materials (metal, cloth, linoleum, other things) to the bottom of the box. Tack or tape them as shown in Figure 4-3.

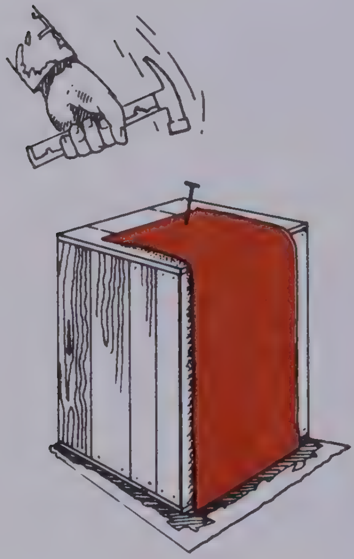


Figure 4-3 *How to fasten materials to the bottom of the box.*

Team 2: Measure the force of friction when the box is (a) on the floor, (b) on rollers, (c) on wheels.

Team 3: Measure the force of friction when the box is empty and when it has different loads. Weigh the box and the loads. Weigh the empty box by hanging it from your spring balance. You can weigh the things you put in it in the same way by tying them with string. Make a graph to show how the friction changes when the total weight changes. The total weight is the weight of the box plus the weight of the things you put in it.

Team 4: Measure the force of friction when the box is pulled as in Figure 4-2. Then measure the force when you pull as in Figure 4-4. Measure the distance AB each time. Use at least three different heights.

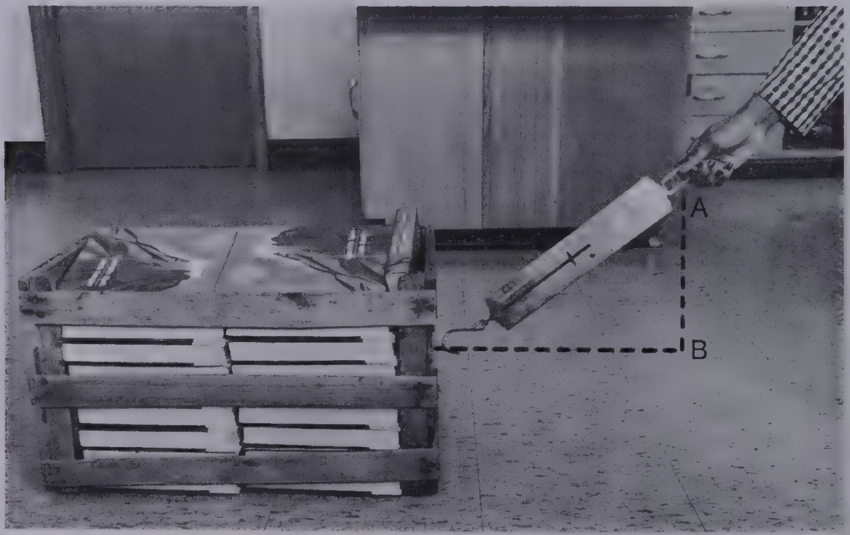


Figure 4-4 *Is it easier to pull at an angle like this, or holding the scale parallel to the floor? How will you measure AB?*

Each team should make a report to the class. Copy in your notebook the observations of the other teams. Make a summary of the observations of each team. ★

4-3 Friction can be controlled

How could you use your knowledge of friction to help the people in Figure 4-5?

One way to cut down friction is to change the surfaces that are slipping. You did this when you put newspaper or pieces of rug under the box. Skiers put wax on their skis to make them slip more easily over the snow. If a drawer sticks, you can sometimes make it slide better by putting wax or soap on the bottom.

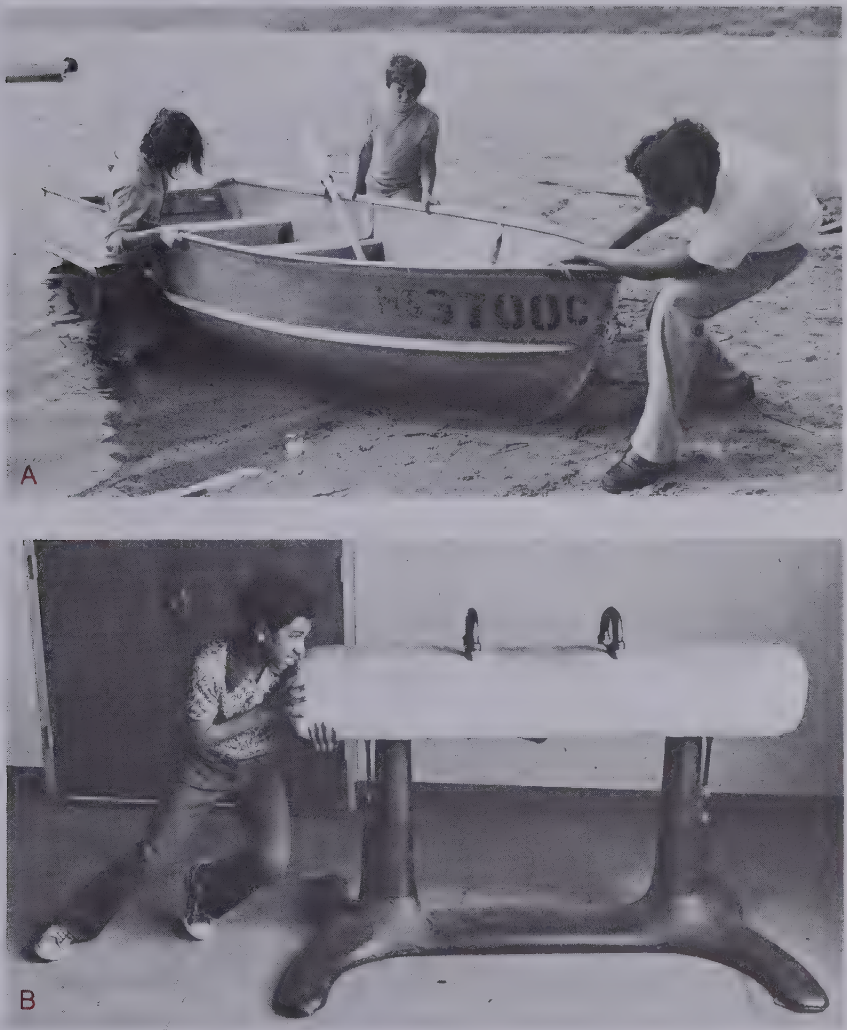


Figure 4-5 *Too much friction.*

When a door squeaks, this is a sign of friction. To fix it, you put a little oil on the hinges. A slippery substance that decreases friction is called a **lubricant** (LOO-bri-kant). Sometimes air is used as a lubricant, as in Figure 4-6.

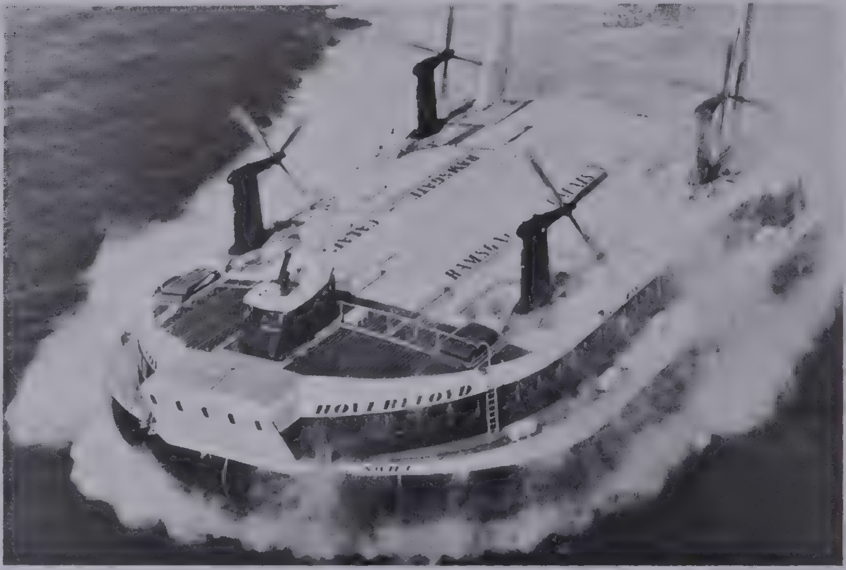


Figure 4-6 *Giant fans give a hovercraft a cushion of air to ride on.*

Did You Get the Point?

The size of the force of friction depends on the kinds of surfaces that are slipping.

Friction is greater when surfaces are pushed tightly together.

It is less when rollers or wheels are used between the surfaces.

It is sometimes less when you pull up at an angle.

Lubrication makes friction less.

What Have You Learned?

1. Ask a shop teacher or a mechanic to show you some ball bearings. Why do they help to make friction less?

2. You can sometimes undo the cap of a jar more easily if you put a towel over the cap before turning. Why does this help?

3. Make a list of situations where friction is a help.

Forces that Turn Things

4-4 Fun with a seesaw

Joe and Paul get on the ends of a seesaw (Figure 4-7). As soon as they sit down, up goes Paul because Joe is heavier.

Joe is laughing, but Paul is mad.

"Let me down," he yells.

This is no way to have fun on a seesaw, with one person in the air all the time. So Joe moves up a bit. They balance and can have fun. Then Joe moves up a bit more. Now Paul is on the ground and Joe in the air. The seesaw doesn't balance.

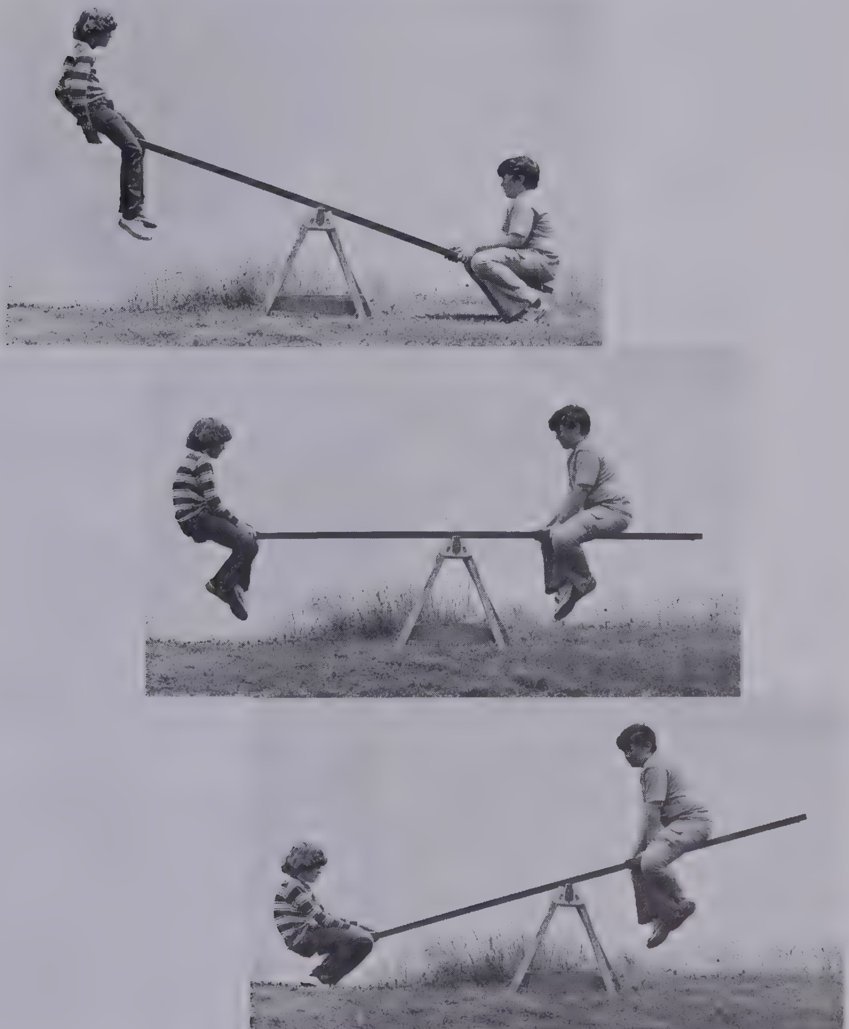


Figure 4-7

Materials
board, dowel, books, blocks, modeling clay, meter stick, chalk

★ Set up a seesaw like the one in Figure 4-8A. If necessary, use extra books to keep the rod from rolling off the piles of books. Be sure the seesaw balances when it has nothing on it. If not, attach some pieces of modeling clay to the high end until it balances. Notice the place marked *fulcrum* in the picture. The **fulcrum** is the point around which the seesaw swings. Draw a chalk line across your seesaw to mark the fulcrum.

Instead of people, you will use blocks on the seesaw. Each block weighs just about the same amount. So you will measure the loads on the seesaw in blocks. In Figure 4-8B, the weight on the right is five blocks. On the left it is four blocks.

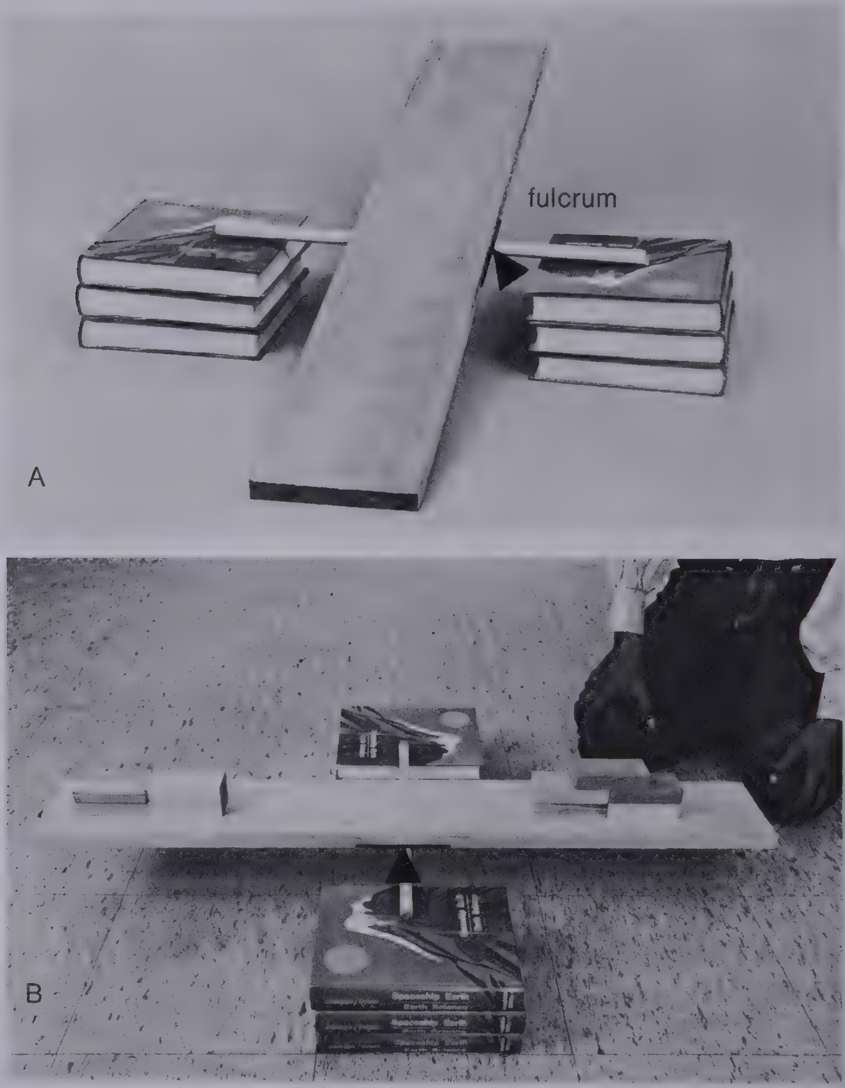


Figure 4-8

Draw a line across the seesaw 40 cm from the fulcrum. Put four blocks there. See how they are arranged in Figure 4-9. Notice that the center of the pile is on the 40-cm line. Now put four more blocks on the other end of the seesaw. Arrange them in the same kind of pile. Move them until the seesaw balances. How far is it from the center of the pile to the fulcrum? Make a table in your notebook like the one below. Record the distance to the pile of blocks on the right. Measure it to the nearest centimeter.

A Weight on left of fulcrum (blocks)	B Distance to fulcrum (cm)	C Weight on right of fulcrum (blocks)	D Distance to fulcrum (cm)
4	40	4	?
4	40	5	?
4	40	8	?
4	40	10	?

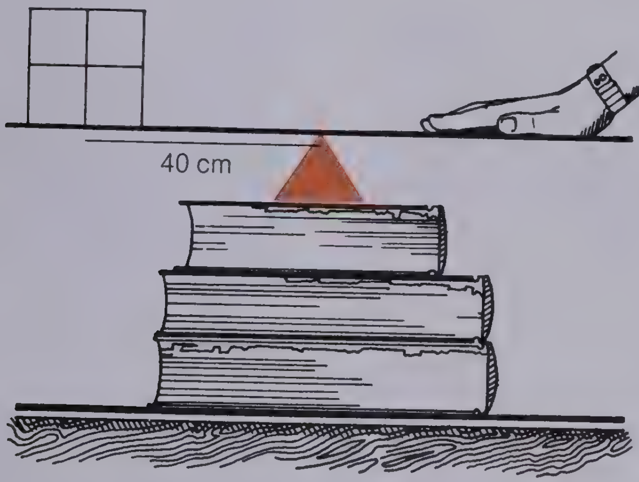
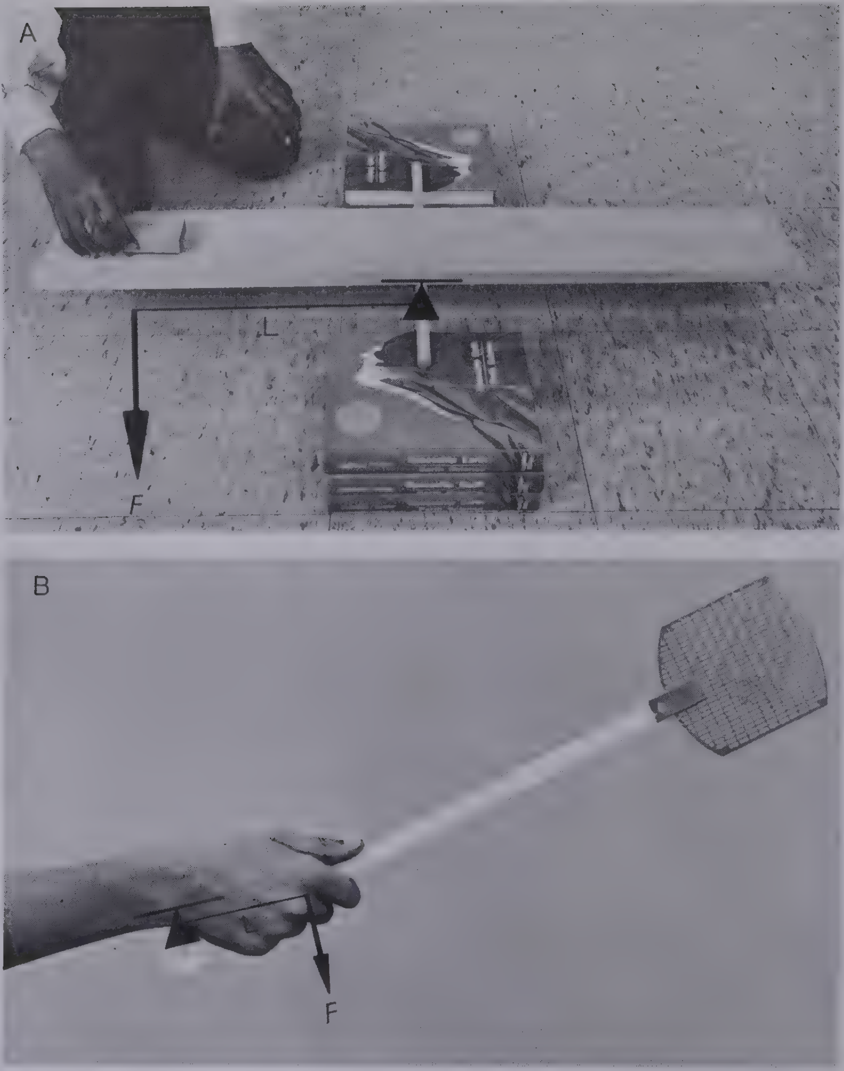


Figure 4-9 *Starting the seesaw experiment.*

Of course the answer you find does not surprise you. The distance is about 40 cm. But you probably cannot guess the distances for the other weights in the table. Try them and record the distances.

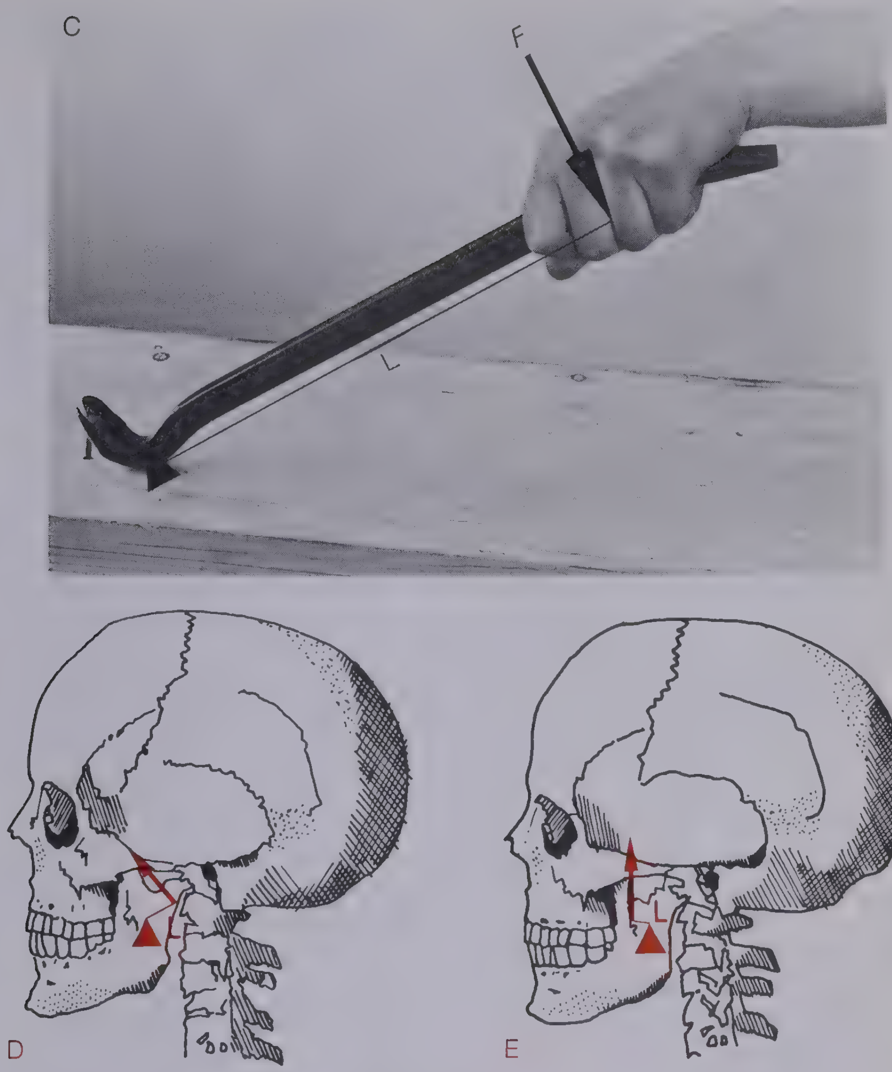
Figure 4-10 *Which way does each lever turn?*



Now the fun begins. Study the numbers in the chart. Try to see how they work. When you have a hypothesis, test it on the seesaw. For example, you might try to guess where to put 16 blocks on the right. Put the 16 blocks at the distance you guessed. Does it balance? If not, try another hypothesis.

Now change the weight on the left to five blocks, still at 40 cm. Balance them with eight blocks on the right. Does the rule still work?

When you are sure you have the correct rule, write it in your notebook. ★



4-5 The law of torques

The seesaw is a lever. Anything stiff that turns when a force is applied to it is a **lever.** In Figure 4-10, there are several levers. Notice that the fulcrum does not have to be in the center. Also the lever can be curved, like your jawbone or a pry bar.

The hands of a clock turn this way ↷ . This is called a clockwise turn. Some things turn this way ↶. This is called a counterclockwise turn. What kind of turn happens in each of the levers in Figure 4-10?

Notice the lines marked L in Figure 4-10. They are called the lever arms of the force. The **lever arm** is the distance from the fulcrum to the force that causes the turning.

In Figure 4-11, two children are on a seesaw. Check your understanding of the definitions by answering these questions:

1. What kind of turn will Sue's weight give the seesaw?
2. How long is the lever arm of Sue's weight?
3. What kind of turn will Mary's weight give the seesaw?
4. What is the lever arm of Mary's weight?
5. The turning effect of a force is called a **torque** (TORK). The torque is the size of the force multiplied by the length of the lever arm. For example, if a force is 2 N and the lever arm is 3 m, the torque is 6 N • m. What is the torque caused by Sue's weight? Is it clockwise or counterclockwise?
6. What is the torque caused by Mary's weight? Is it clockwise or counterclockwise?
7. When the clockwise torque equals the counterclockwise torque, the seesaw will balance. Is this true for Sue and Mary? Was it true for the seesaw you used in your experiment, allowing for a small error of measurement?
8. If Mary moves out to the end of the seasaw (1.5 m from the fulcrum), what will be the torque caused by her weight? Will the seesaw balance?

The rule you discovered in your experiment is called the **law of torques.** It is: An object that can turn will balance if the clockwise torque equals the counterclockwise torque.

Figure 4-11 *Look at this picture carefully. Then answer the questions in the text.*

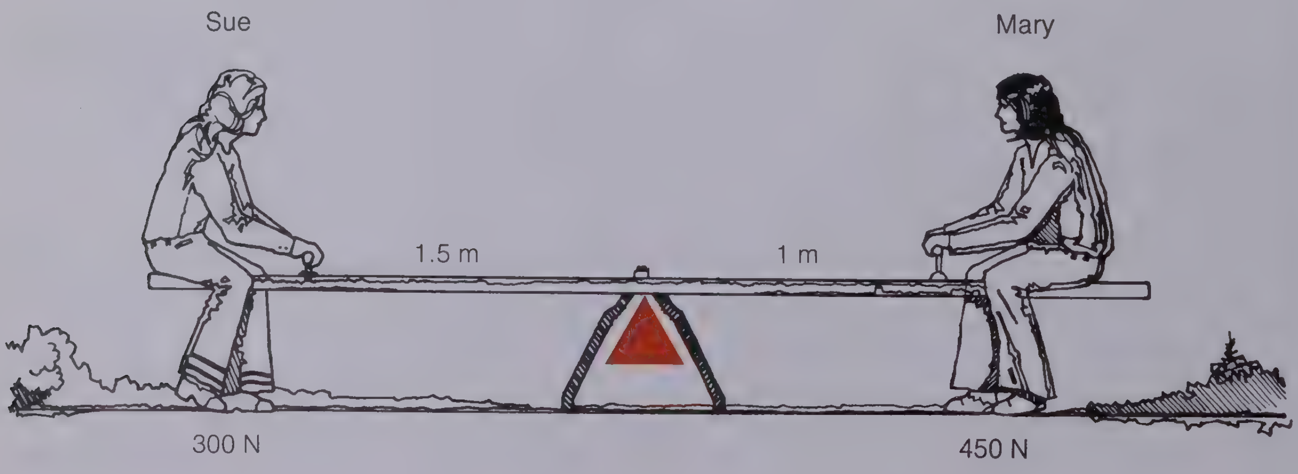


Figure 4-12 shows several bars with forces acting on them. Decide in each case whether the bar balances or not. If it does not, then tell which way it will turn. Be careful, one of these is tricky.

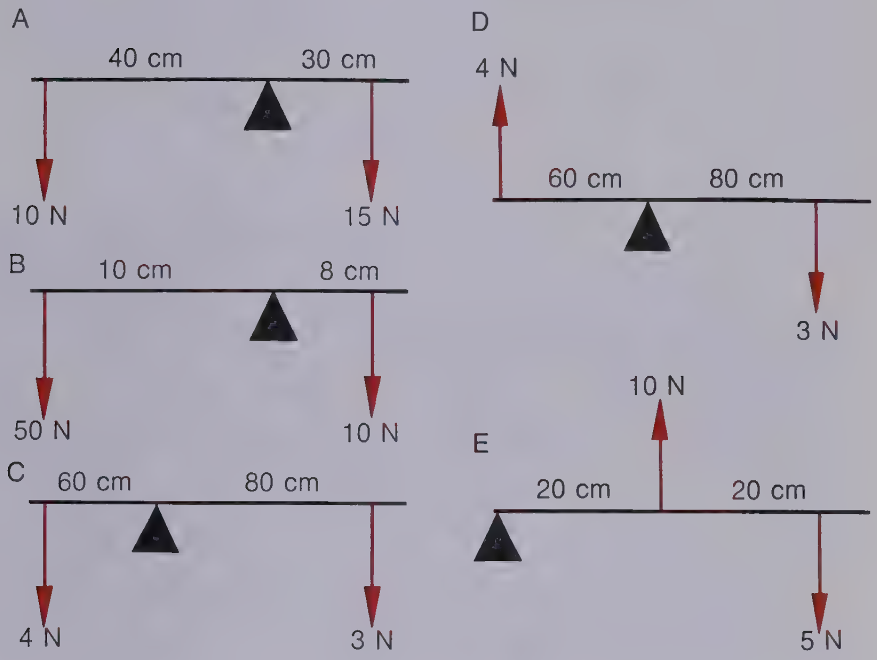


Figure 4-12 *Which levers balance? Which way will the unbalanced levers turn?*

4-6 The adventure of the bank robber's money

A bank robber escaped into the woods. He had half a million dollars. The police were sure they would find him, because the bills were all marked. Months went by. None of the money appeared. Gary and Luis lived near the woods where the robber disappeared. So one day they went looking for the money. Luis stopped and looked at a big rock. "There's something sticking out from under it. Maybe it's the bag of money."

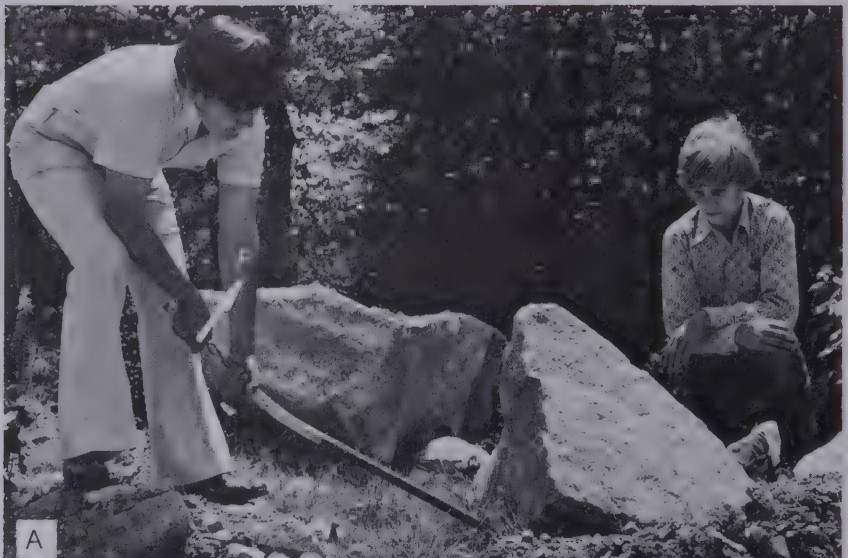
"If it is, we'll get a reward," said Gary. "Let's move the rock."

They tried to push the rock, but it would not budge. They got an iron bar. Luis put it under the edge of the rock and pushed (Figure 4-13A). No luck.

"What we need is a fulcrum," said Luis.

So he got a small stone and put it under the bar (Figure 4-13B). He pushed down on the end of the bar. Nothing happened. Then he stood on the end. Slowly the rock lifted.

Figure 4-13 (*A*) *This way the rock didn't budge.* (*B*)*With a fulcrum, the rock moved when Luis stood on the bar.*



Gary pulled the bag out and opened it. "Hundred-dollar bills! There must be hundreds of them."

"Let's take them to the bank," said Luis.

The banker looked at the bills. "These are counterfeit. They must have been hidden by that gang that got caught last week. Sorry I can't give you a reward for this, but you'll sure get your pictures in the paper."

How did Luis lift the rock? He was using the bar as a lever. At first he used a force of 10 lb. How much force could he apply to the rock? To get the answer, study Figure 4-14. The bar balances when the two torques are equal. As you see from the drawing, this happens when the force at the rock is 200 lb. This is 20 times as big as the force Luis used. But it is less than the weight of the rock. Now you figure out how much the force at the rock is when Luis steps on the bar. Luis weighs 150 lb. First find the torque at Luis's end. Then find how much force at the rock makes the same torque. This force is greater than the weight of the rock, so up goes the rock.

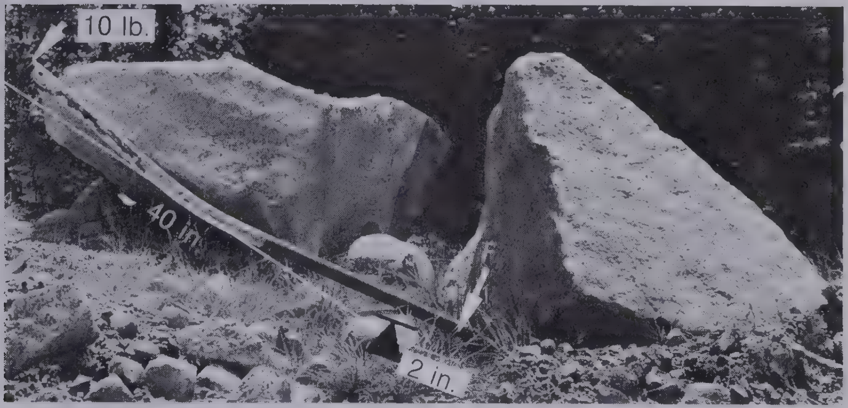


Figure 4-14 *How to calculate the torques for Luis and the rock.*

The beautiful thing about Luis's lever is that he can use a small force at his end to make a very big force at the other end.

4-7 The lever is a useful machine

Luis's lever is a machine. So are the other levers in Figure 4-10. A **machine** is anything that makes it easier or more convenient to use a force to move something. Probably most people think that machines are like cars and trains. Those are complex machines. Levers are simple machines. See if you can find the levers in the bicycle in Figure 4-15. Complex machines are made of many simple machines. Some machines are worked by hand. Others need motors to keep them going.

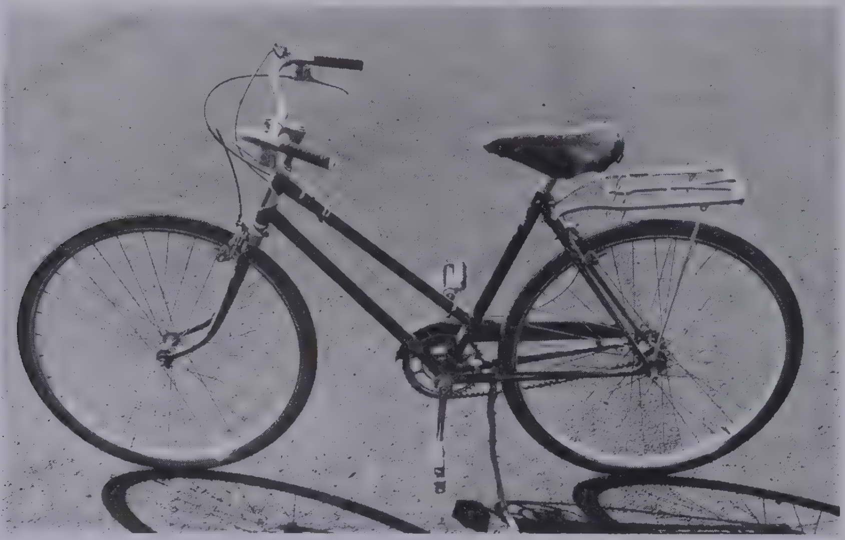


Figure 4-15 *How many levers can you find on the bicycle?*

The force applied to a machine is called the **input force.** For Luis's lever the input force was 10 lb (Figure 4-14). The force at the other end of the machine is the **output force.** For Luis's lever the output force was 200 lb. The output force was 20 times as big as the input force. This number is called the mechanical advantage, abbreviated MA.

$$\textbf{mechanical advantage} = \frac{\text{output force}}{\text{input force}}$$

There is an easy way to change the mechanical advantage of a lever. Move the fulcrum. Suppose Luis moves his small stone so it is only one inch from the place where the bar touches the rock. Keep the input force at 10 lb. Find (a) the torque on his side, (b) the force on the other side that gives the same torque, (c) the mechanical advantage.

Look at these two MA's. Do you see another way to find the MA of a lever?

Tinsnips, like those in Figure 4-16A, are made of two levers fastened together at the fulcrum. What is the MA? What happens to the MA as the tinsnips cut into the metal?

Probably most people would not think that a fishing rod is a machine, but it is. The boy in Figure 4-16B has just hooked a 3-lb fish. How hard must he pull to lift it out of the water? What is the MA? Why is this machine useful?

In Figure 4-16C, the load is spread out over the wheelbarrow. On the average it is about 1 ft. from the axle of the wheel. The axle is the fulcrum. How much force must the woman use to lift the load? What is the MA?

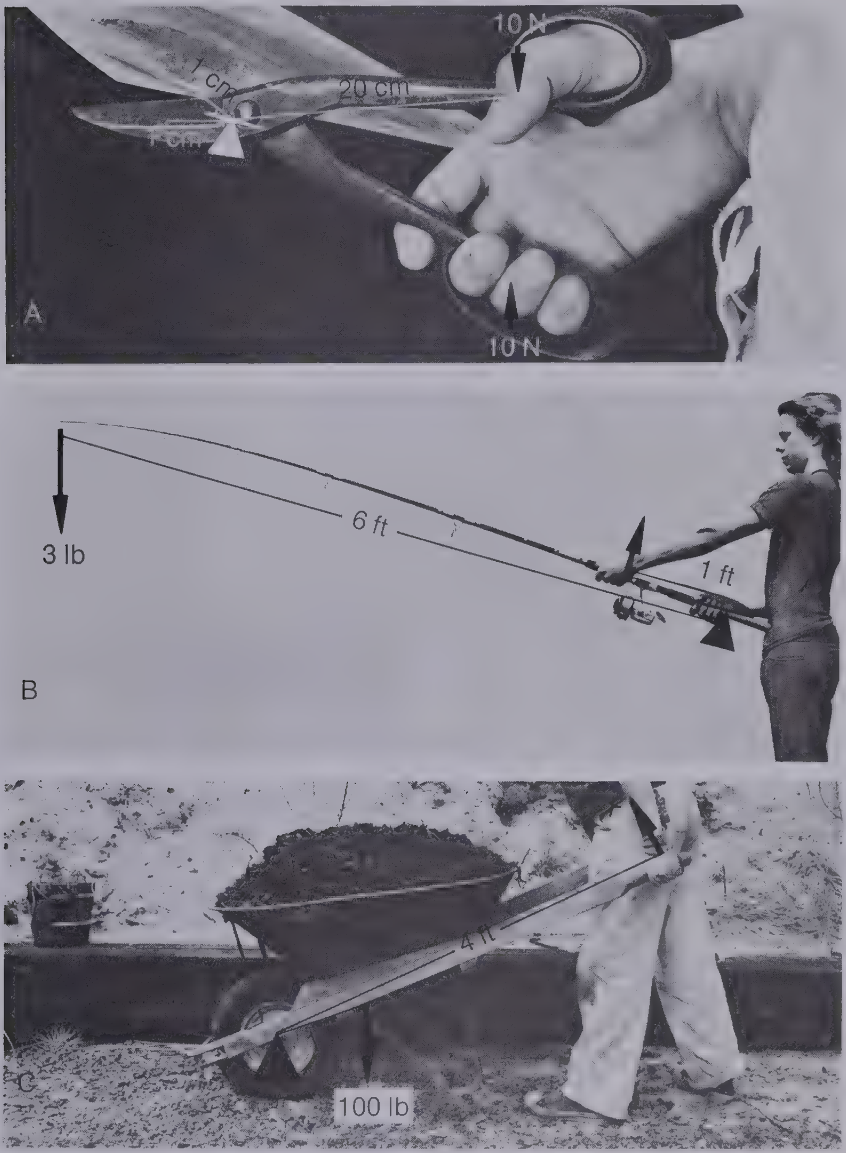


Figure 4-16 *What is the mechanical advantage of each lever?*

Did You Get the Point?

The turning effect of a force is called a torque. The torque is the size of the force times its lever arm.

The greater the torque, the greater its ability to make something turn.

An object will balance if the clockwise torque equals the counterclockwise torque.

A lever is a useful machine that uses the law of torques.

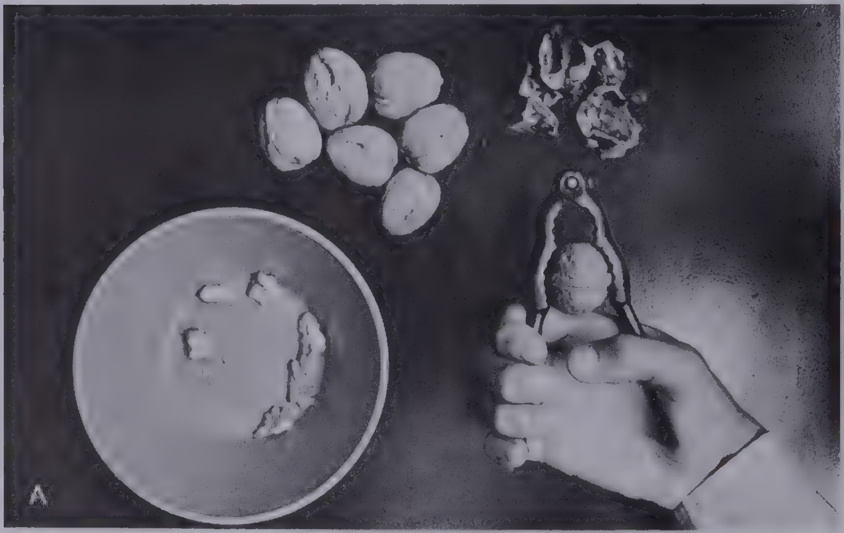
What Have You Learned?

1. In Figure 4-10B, which is bigger, the force marked *F* or the force on the fly when the swatter hits it? How do you know? Why is it easier to kill a fly with a swatter than with your bare hands?

2. In Figure 4-10C, which is bigger, the force marked *F* or the force on the nail? How do you know?

3. Why are doorknobs or push plates put near the edge of a door instead of in the middle?

4. The law of torques is used in each of the pictures in Figure 4-17. For each one, answer these questions: (a) Where is the fulcrum? (b) Is this a machine? (c) If it is a machine, is the MA greater or less than 1?



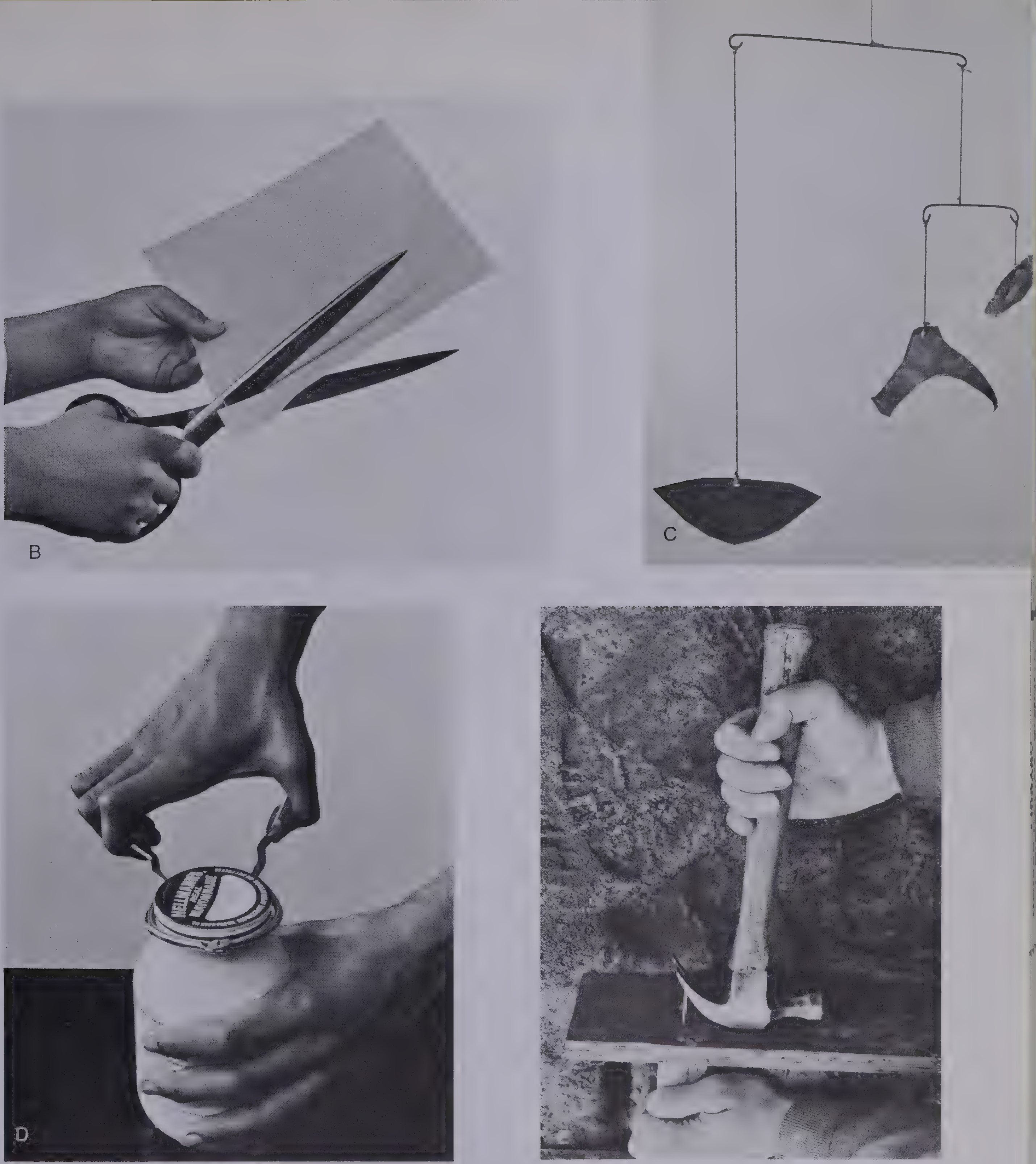


Figure 4-17 *Use these pictures to answer Question 4.*

5. In Figure 4-18, the people's jobs would be easier if they used levers. Explain.

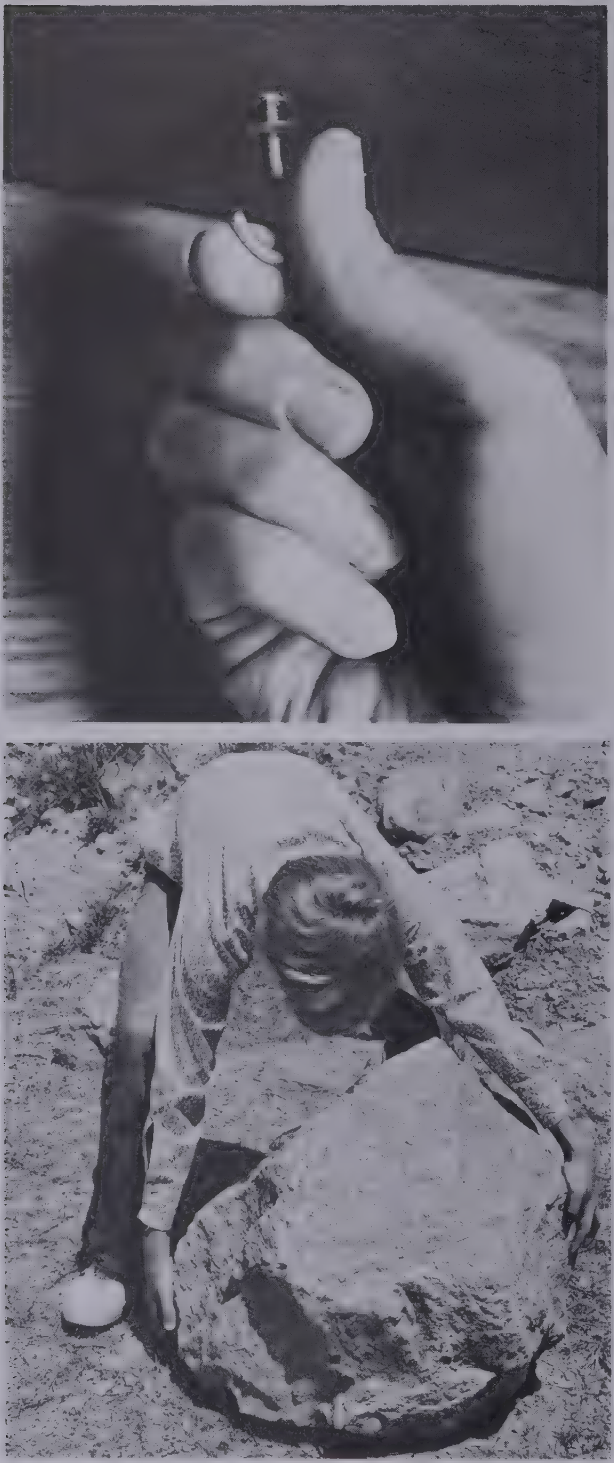
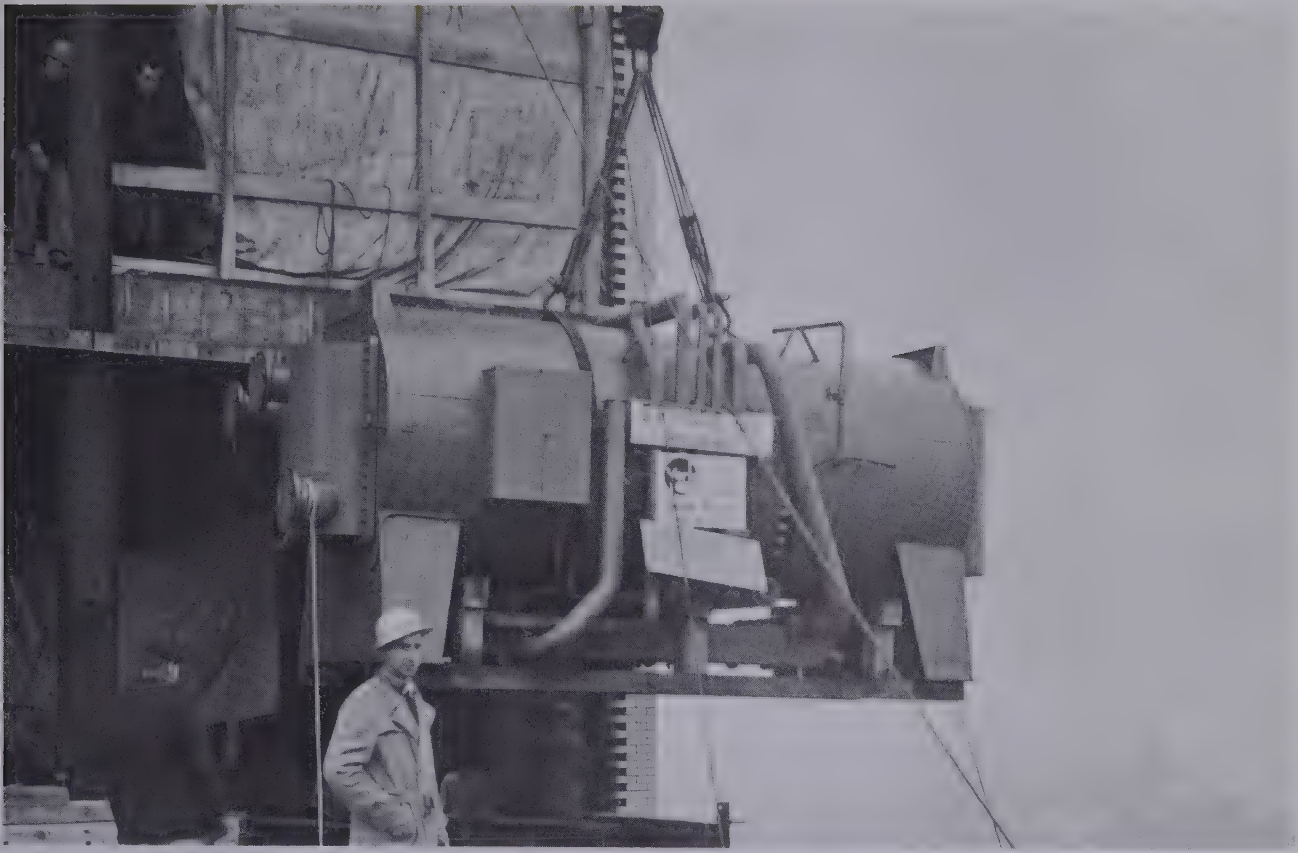


Figure 4-18 *Use these pictures to answer Question 5.*



RIGGER

A rigger is a person who needs to know easy ways to do a job. Riggers put together the rigging used to lift and move things. A rigger may have to lift a stack of steel beams, move a section of a ship's hull, or unload a piece of heavy machinery from a truck. He uses bigger and more complicated versions of the simple machines you have used in laboratory activities.

A rigger first estimates the weight of the object to be moved. Then he figures out what machine can do the job best. He attaches cables, ropes, or a sling to the load. While the object is moving, the rigger directs the crane or hoist operator with hand signals. The safety of the load—and of anyone nearby—is the responsibility of the rigger.

The best training a rigger can get is as an apprentice. That takes three or four years working with experienced riggers. Most riggers are high school graduates with a knowledge of practical mathematics or shop geometry.

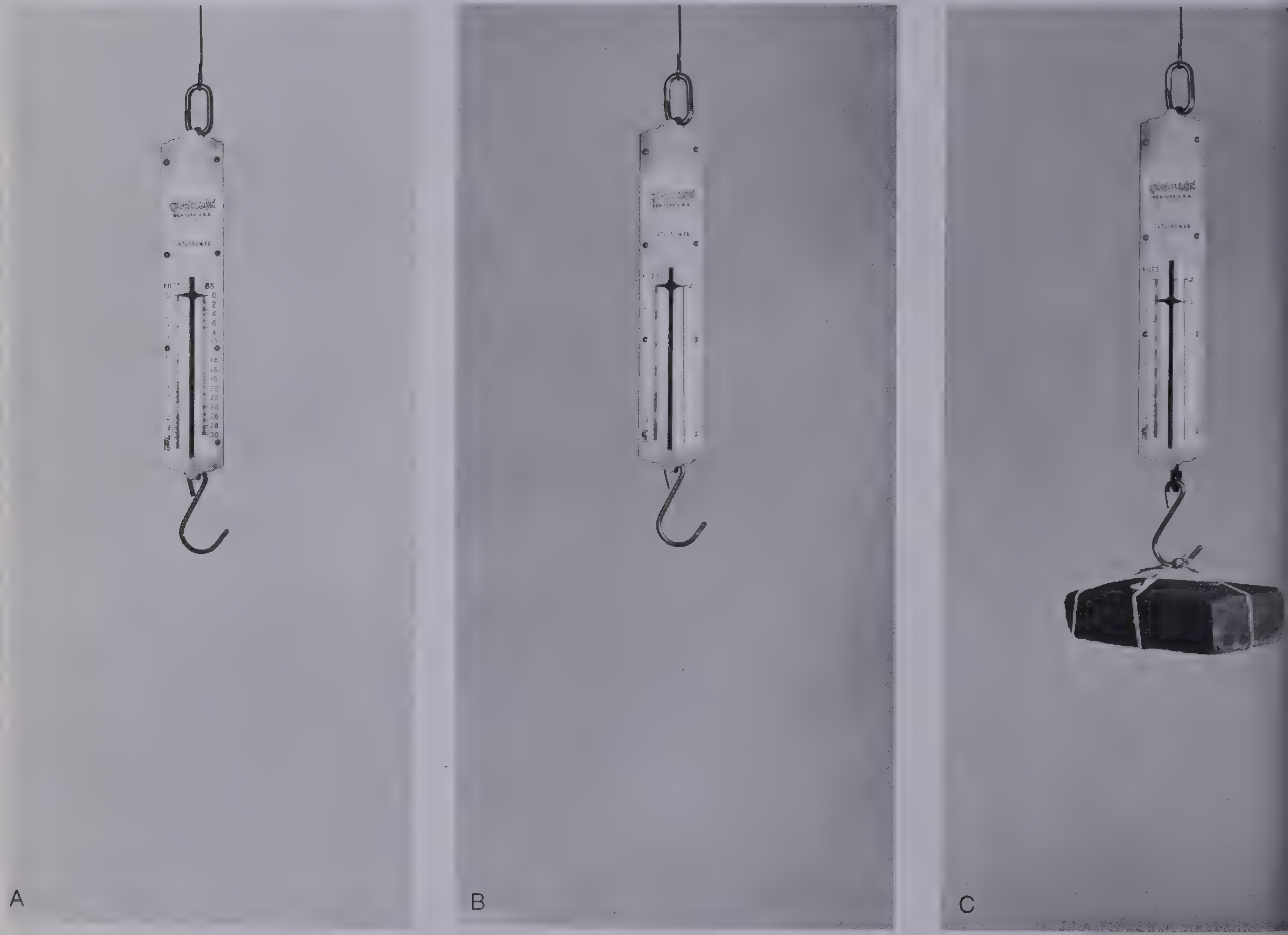
Other Simple Machines

4-8 Raising heavy loads

Materials
machine, rope, meter stick, spring scale, bricks, bag

★ Each team will have one machine. Your job is to find the input and output forces and the mechanical advantage.

The input force is how hard you have to push or pull to do the lifting. The output force is the weight of the load. To get the input force, use a spring scale. See Figure 4-19 for directions about how to fix the scale. Figure 4-20 tells you how to use it.



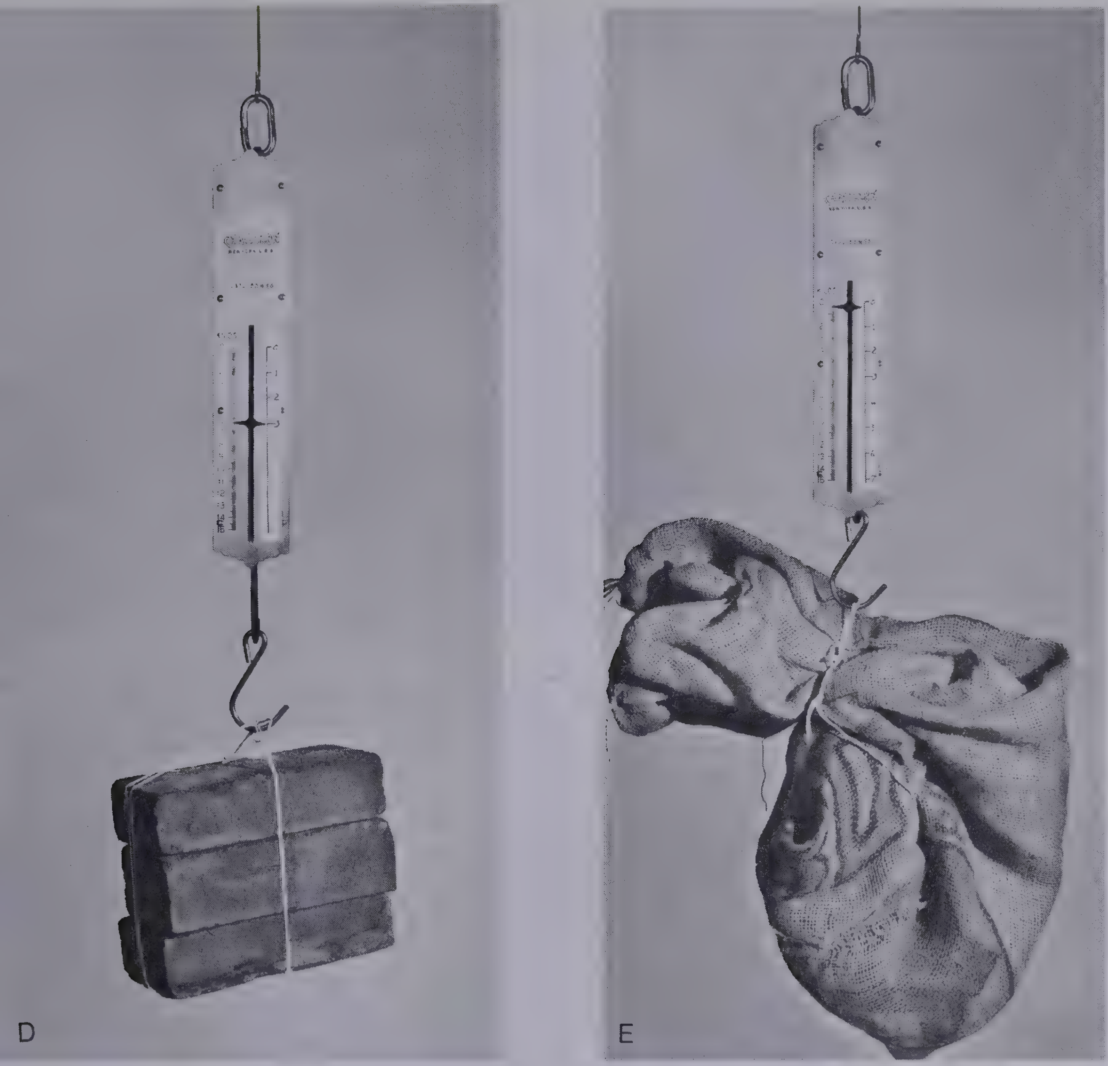


Figure 4-19 (*A*) *Your spring scale does not measure weight in bricks.*
(*B*) *Cover one side of the scale with tape. Mark the 0 point on the tape.*
(*C*) *Hang one brick on the scale. Mark 1 where the pointer is.*
(*D*) *Repeat with 2, 3 and more bricks, until the pointer can't go any farther.*
(*E*) *Weigh the bag you will use to hold the bricks. Figure its weight to the nearest tenth of a brick. Write this number in your notebook. When you use a machine to lift a bag of bricks, the output force is the number of bricks plus the weight of the bag.*

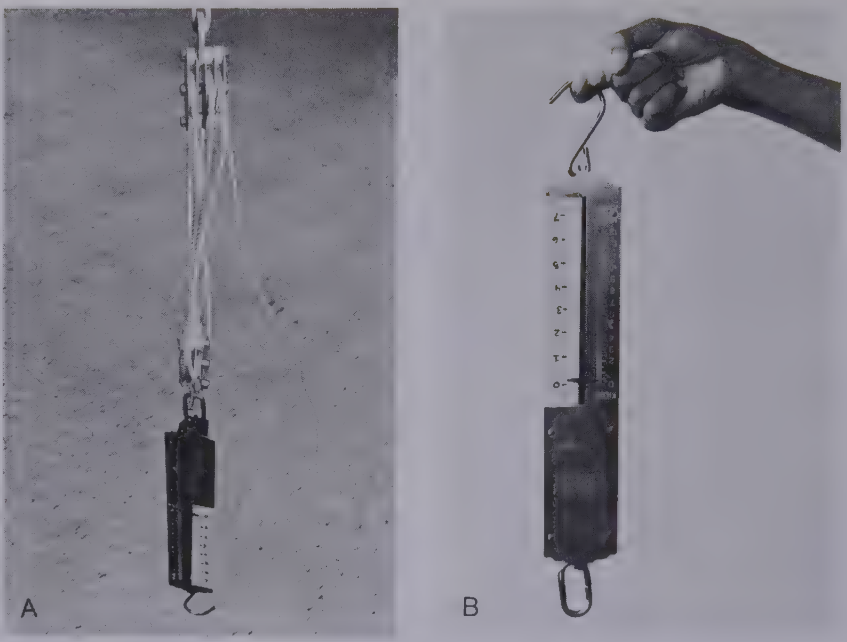


Figure 4-20 *(A) The scale reads 0 when it hangs right side up.*
(B) The scale does not read 0 when it hangs upside down.
(C) Hang the spring scale upside down on the block and tackle. Pull on the ring.
(D) Hang the spring scale upside down on the handle of the winch.
(E) When you pull a load up an inclined plane, it does not matter whether the spring scale is right side up or upside down.

In your notebook, make four columns: name of machine, input force, output force, MA. The MA will probably not be a whole number. Find it to one decimal place. After you have done this once, repeat with a different load.

Examine the machines used by other teams. Record their measurements in your notebook also. ★

4-9 Can you change the MA of your machine?

Materials
machine, rope, meter stick, spring scale, bricks, bag

★ With some machines you can easily change the MA. With others you cannot. Experiment with your machine to see whether you can change it. Try different loads, different angles (inclined plane), different crank lengths (winch).

If you cannot change the MA of your machine much, see whether someone else has a similar machine. Does it have the same MA as yours? If not, find out what is different about the two machines. ★

4-10 Some machines can run backwards

In Figure 4-21 you see the same machine used two different ways. In the second picture, the input and output forces have changed places.

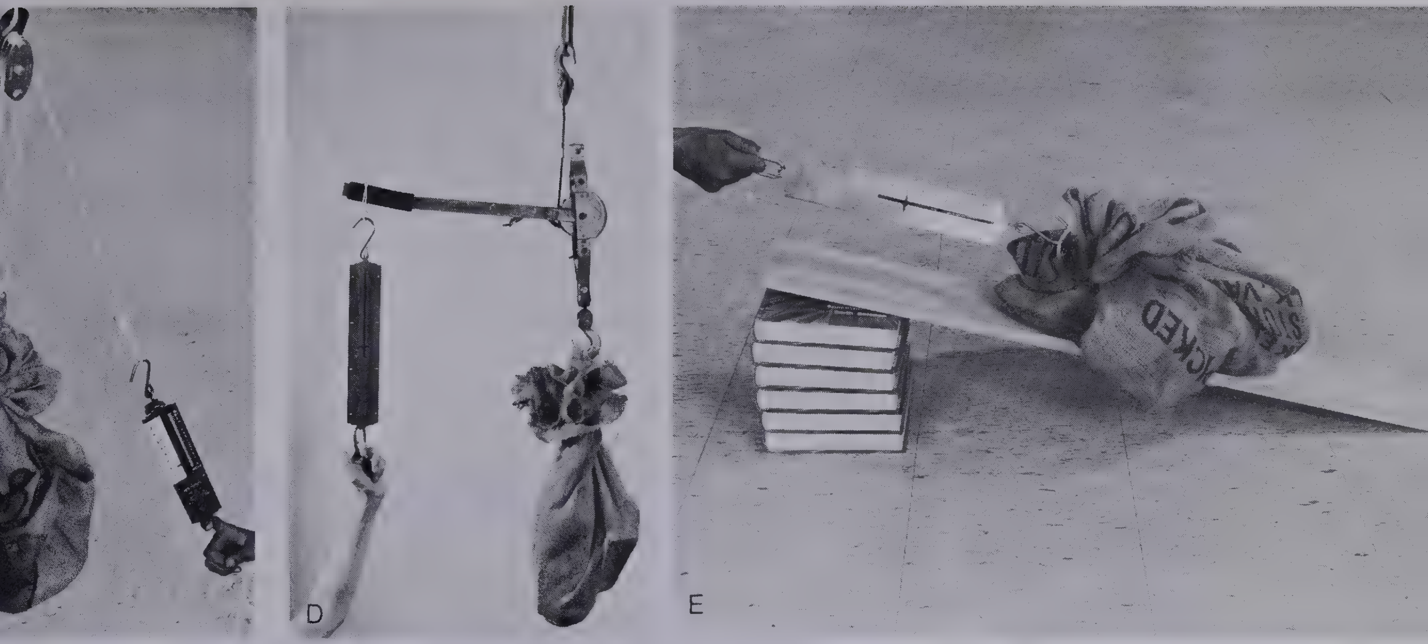
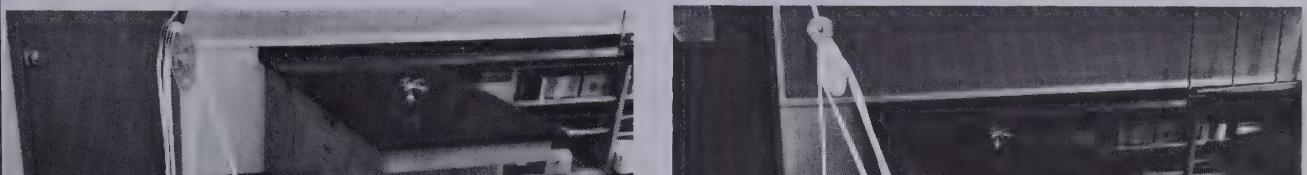


Figure 4-21 *(A) A block and tackle. (B) The same machine working backwards. In which picture is it harder to pull up the box?*



★ Some of the machines in your class can be run backwards like this. See what happens when this is done.

Measure the two forces. Which is greater? What is the MA? When you pull to make the input force, notice how far your hand moves and how far the load moves. Which moves faster, your hand or the load? How could a machine like this be useful?

Just for fun: for students who cannot run their machines backwards, or anyone else who wants to do it. Find the MA of a single pulley, as shown in Figure 4-22. Would a single pulley like this be of any use? Why? ★

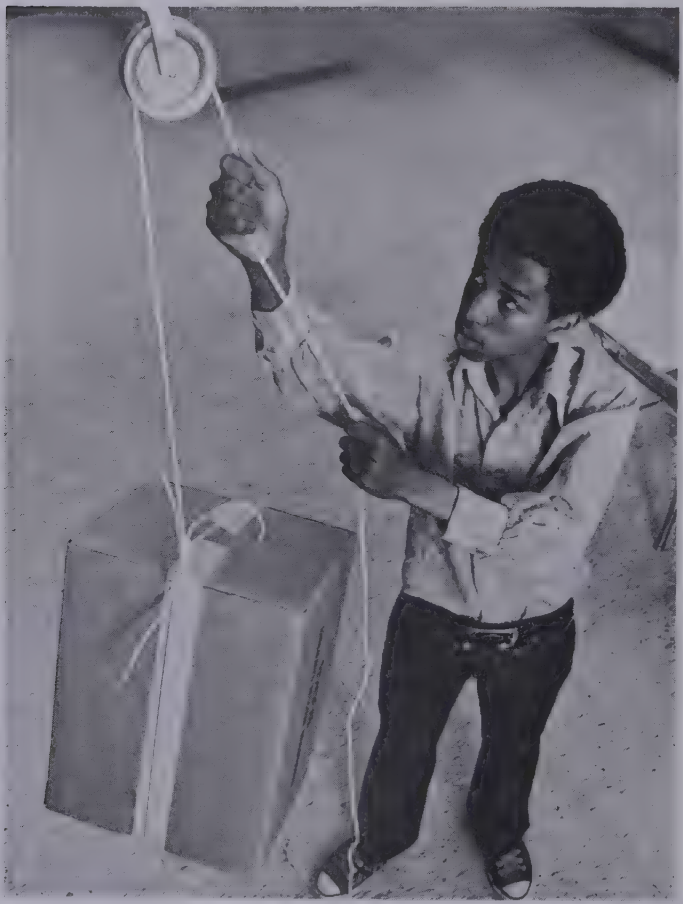


Figure 4-22 *A single pulley.*

Did You Get the Point?

The chain hoist, block and tackle, winch, and inclined plane are simple machines.

With some machines, a small input force can lift a heavy load. The MA of these machines is greater than 1.

With other machines, the input force is greater than the load. Their MA is less than 1. These machines are useful in moving small loads rapidly.

What Have You Learned?

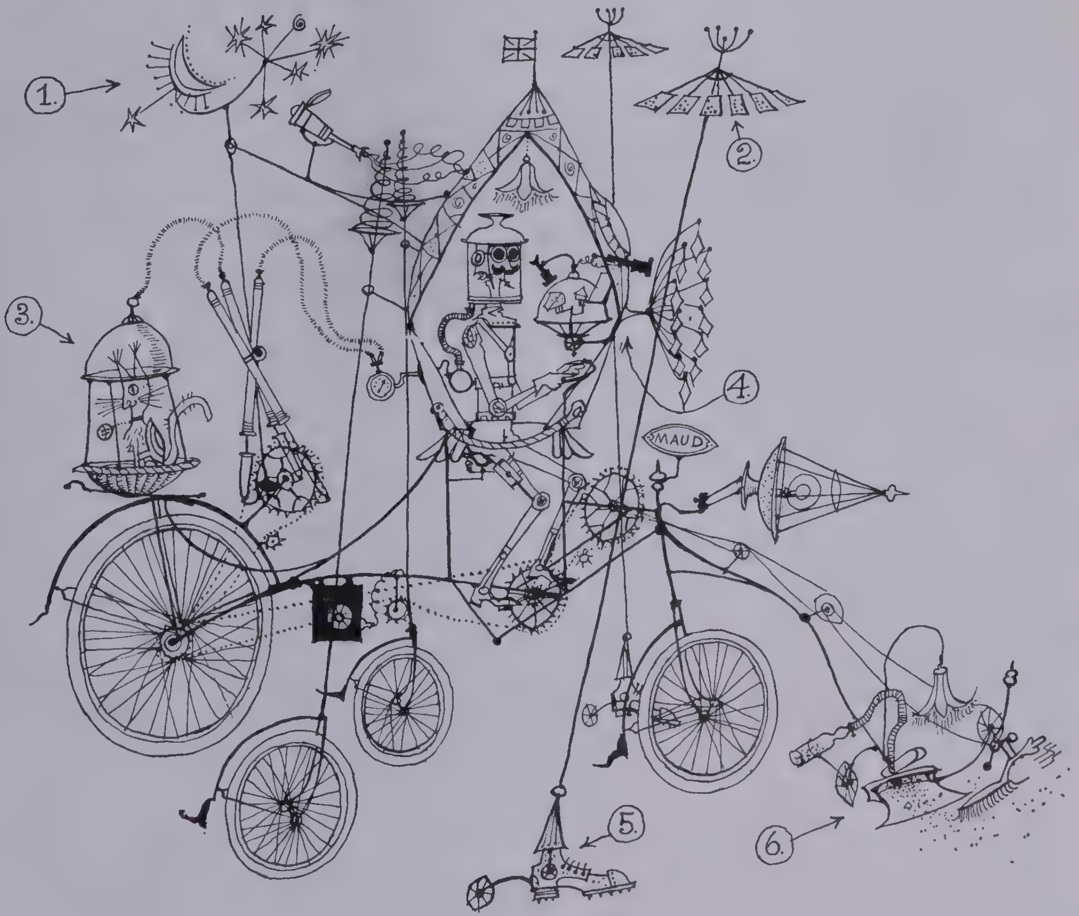
1. Have you ever seen workmen use machines like the ones you used? Describe the uses.

2. Do all machines have moving parts?

3. See if you can find one or more simple machines in your house. If possible, bring one to school. Is it used to move heavy loads or for speed?

4. Figure 4-23 shows a not-very-useful machine. See how many different simple machines you can find in it.

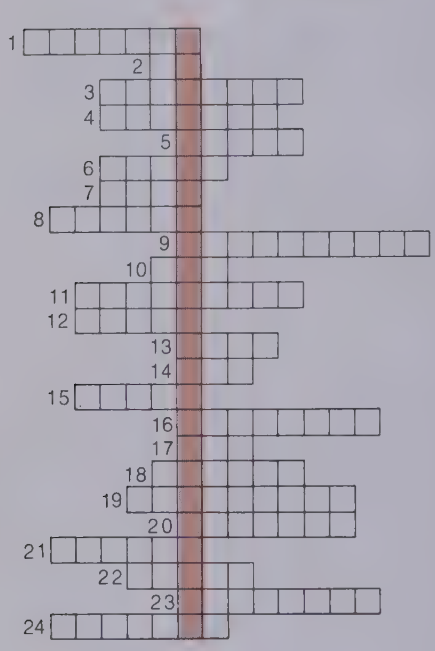
igure 4-23 *This machine is an inventor's idea of the perfect ay to travel on the moon.*



SKULLDUGGERY

1. Whenever you come to a number in the paragraph below, try to think of the missing word. For example, the first missing word is number 17. The word is JOB. Your teacher will give you a copy of Figure 4-24. Fill in the word JOB in the squares for number 17. Do this for as many words as you can. If you get them all, the letters in the vertical box will make a sentence about what you have learned in this chapter.

Figure 4-24 *Puzzle for Skullduggery 1.*



If you want to pry something up, you can make the (17) easier by using a (15). Every lever must have a place where it turns. This place is called the (1). The (16) from the fulcrum to the force is called the lever (14). If you multiply the lever arm by the (12), you get the (18) of the force. A lever balances when the counterclockwise torque equals the (11) torque. This rule is called the (10) of torques. A garage mechanic uses a (22) hoist to lift the engine from a car because the hoist has a large (2). Another (4) that could be used to lift something heavy is a block and (21) made of several (24) and a (7). Some students were using an inclined (6). They found that a force of one brick would pull a 16-brick load up the slope. Therefore, the (9) advantage of the machine was (20). They decided to decrease the (3) by putting the bricks in a wheeled cart. When they did that, they found that they could pull up 25 (8) with an (5) force of one brick. Friction is a force that always opposes (23). You need friction to (13) you to walk. But friction is bad in car wheels, so grease is used for a (19).

2. You can find the MA of a bicycle. Get several bikes of different kinds—1, 3, 5, and 10 speeds. Maybe a bicycle store will let you do the experiment there. To test the MA of a bicycle, set it to the lowest gear. Move the pedal a certain amount, like 10 cm. Measure how far a point on the back wheel moves. Divide the first distance by the second distance to get the MA. Set the bicycle to the highest gear and do the same thing. Do this for each of the bicycles.

Is the MA of a bicycle usually greater or less than 1? Why? Which bicycle would be best for racing? Which would be best for riding in hilly country? Do you think a 10-speed bicycle is worth the extra money?

FOR FURTHER READING

Boumphrey, Geoffrey. *Engines and How They Work,* rev. ed. New York: Franklin Watts, Inc., 1967. From steam engine to rocket engine. Comprehensive survey.

Pine, Tillie S., and Joseph Levine. *Simple Machines and How We Use Them.* New York: McGraw-Hill, Inc., 1965. A clear and useful explanation of simple machines.

Walton, Harry. *How and Why of Mechanical Movements.* New York: Popular Science Publishing Co., Inc., 1968. Describes exactly how machines work.

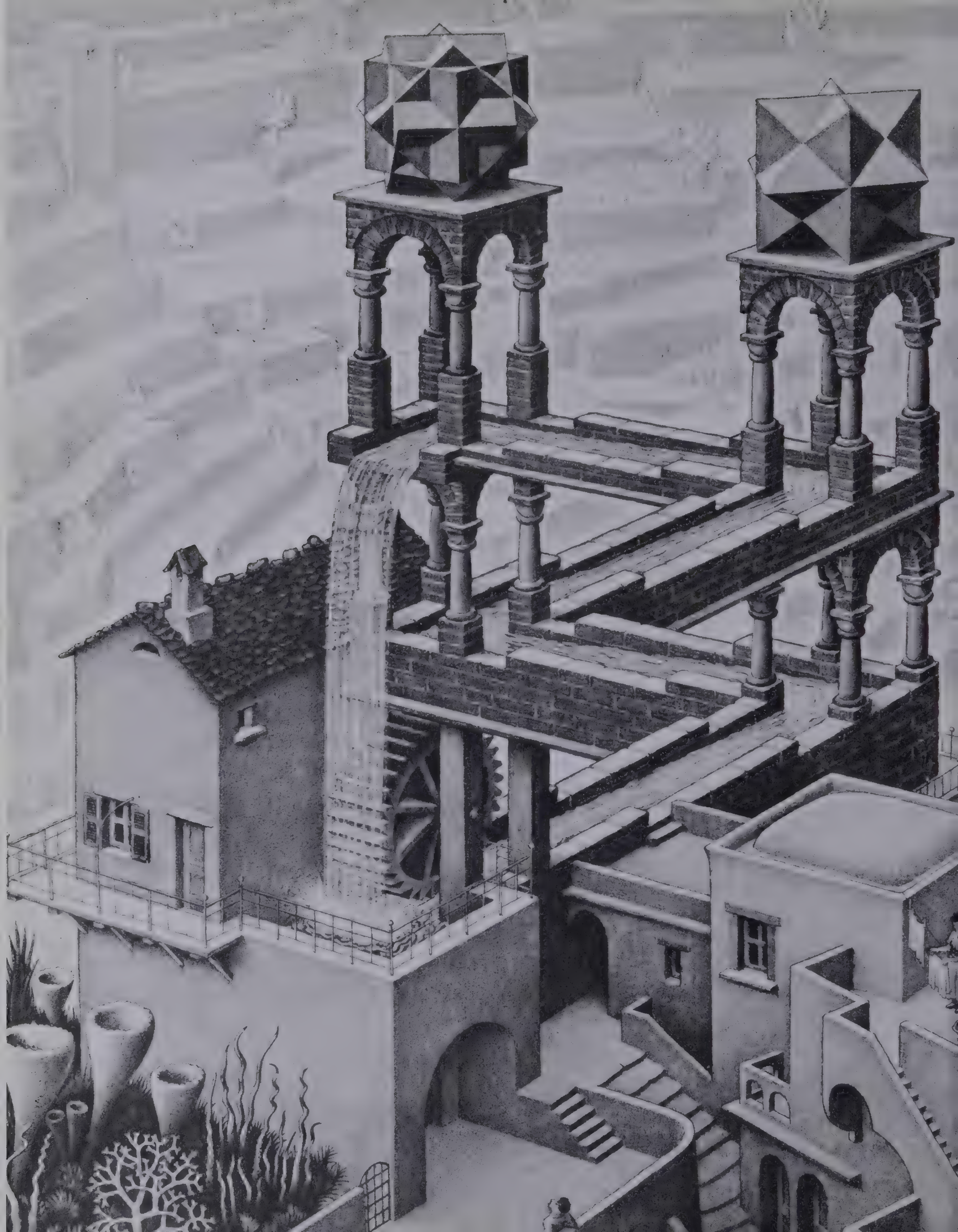
Zim, Herbert S., and James R. Skelly. *Hoists, Cranes, and Derricks.* New York: William Morrow and Co., Inc., 1969. Explains the three basic types of lifting machines.

WHAT'S NEXT?

Cinderella's Fairy Godmother waved her magic wand and wonderful things happened. Mice and a pumpkin became a fine coach with horses to pull it. Cinderella's rags turned into a beautiful gown. Her hair was suddenly high on her head, sparkling with jewels.

Machines are not magical, but they are almost as amazing as the Fairy Godmother's wand. A Greek scientist, Archimedes (Ark-i-MEE-dees), who lived more than 2000 years ago, said "Give me a place to stand and I will move the earth." He meant that he could pry up the earth with a long enough lever. All he would need would be a good fulcrum. And of course he was right. The only trouble is that there is no place to stand, and no place for a fulcrum.

When machines use small forces to lift very heavy things, it seems almost magical. But this is a real world, not a fairy-tale one. There must be a catch. You can't get something for nothing. The next chapter tells how you pay the price.



Chapter 5

Energy

Maurits Escher, a Dutch artist born in 1898, has done many pictures that are fun to look at. This one is called "Waterfall."

This strange river is turning a water wheel. Follow the path of the water. Notice that it goes back over the same wheel. If you had a river like this, you could use the wheel to make electricity to run machines. You would never have to worry about dry spells. The river runs round and round. The wheel turns forever.

People call a thing like this a perpetual motion machine. It works all the time and never slows down. It does not need new water or coal or oil to keep it going. Some people say such machines are possible. Some say they are not. You will have a better idea about who is right when you have finished this chapter.

Can You Get Something for Nothing?

5-1 What do you pay for mechanical advantage?

Materials
machine, spring scale, bricks, bag

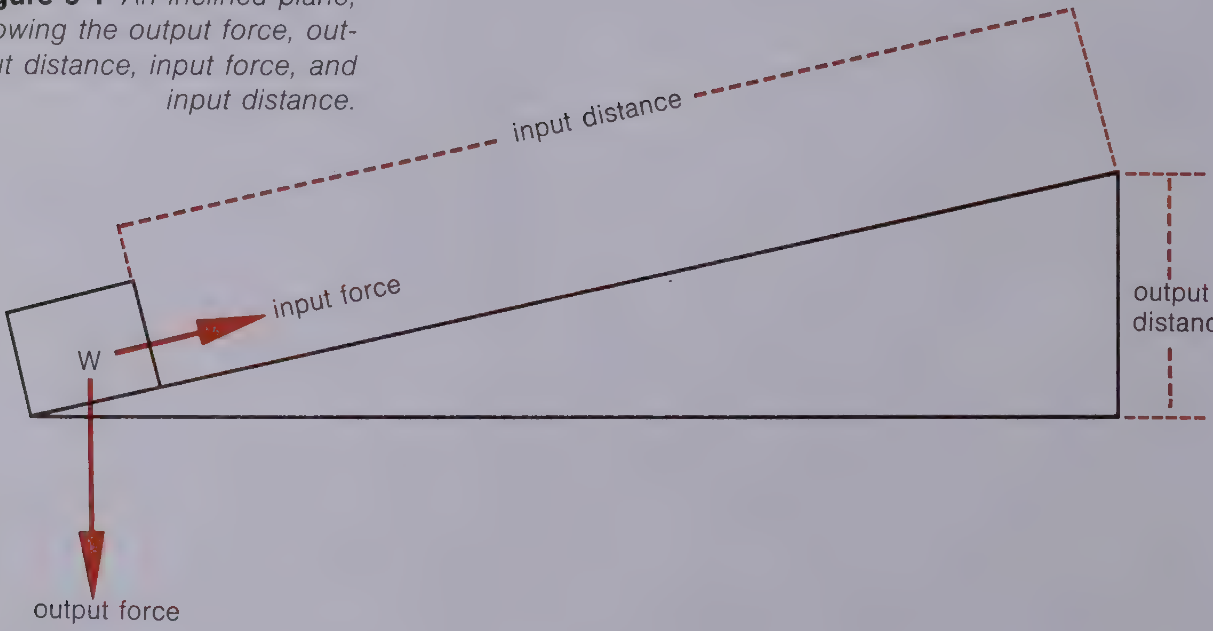
★ Set up your machine (either the one you used before, or another one). This time you will measure four things:

1. The **output force** (the load that is lifted). Measure it in newtons. Remember that when your spring scale says 1 kg, this is 10 N.
2. The **output distance** (the height the load rises).
3. The **input force** (the force you use to make the machine go).
4. The **input distance** (the distance the input force moves the load).

These four things are shown for an inclined plane in Figure 5-1.

Record your observations in your notebook. Then discuss this question in class: When you use a small force to lift a large load, what is the price you pay? The answer is your interpretation. Write it in your notebook.

Figure 5-1 *An inclined plane, showing the output force, output distance, input force, and input distance.*



Make a table like the one in Figure 5-2. List the measurements from all of the machines used in your class. Fill in columns 4 and 7 by multiplying.

Figure 5-2

1 Name of Machine	2 Output Force (newtons)	3 Output Distance (meters)	4 Output Force × Output Distance	5 Input Force (newtons)	6 Input Distance (meters)	7 Input Force × Input Distance
?	?	?	?	?	?	?

For each machine, compare column 4 with column 7. What do you discover? You will find one thing that is always true. Write this in your notebook. Look again at the observations. Try to make a hypothesis about your discovery. Then test the hypothesis. ★

5-2 Force times distance equals work

When a force acts through a distance, the product (force times distance) is called work.

work = force × distance
(measured in the direction of the force)

Notice that part about measuring the distance in the direction of the force. Figure 5-3 shows what this means.

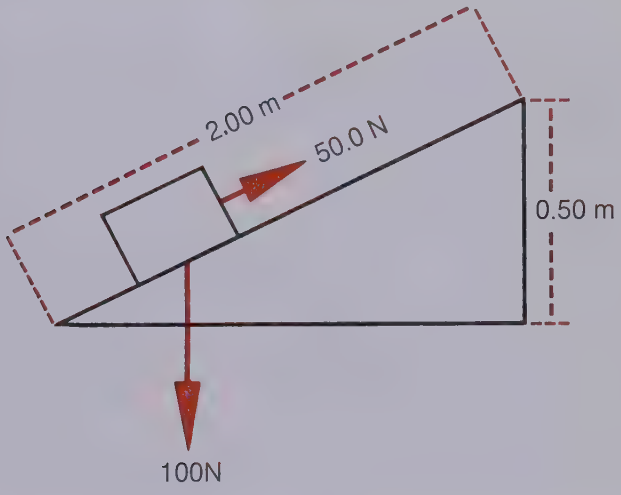


Figure 5-3

The output force is the weight of the load (100 N). The direction of this force is down. To find the work output you must multiply the size of the force by an up-and-down distance. The up-and-down distance is the height of the slope (0.50 m). Therefore

$$\begin{aligned}\text{work output} &= 100\ \text{N} \times 0.50\ \text{m} \\ &= 50\ \text{N} \cdot \text{m}\end{aligned}$$

Notice that the answer is in **newton-meters.** This is because newtons were multiplied by meters to get it. Now find the work input. Remember that the force and distance must be measured in the same direction.

You can now put new labels above two columns in the table in your notebook. Get the labels from these definitions:

work input = input force × input distance
work output = output force × output distance

Which is greater, work input or work output? Why? How can you make them more nearly equal?

To a scientist, the word *work* means exactly what the definition says, exerting a force through a distance. When you sit quietly doing your homework, are you working? Your heart is working. Its strong muscles push the blood. They exert a force through a distance. Your eye muscles are working. They exert a force through a distance to turn your eyes. The muscles that help you to breathe are exerting forces through distances. In many parts of your body work is being done.

However, from the outside point of view, you do not seem to be doing much work. When you lift your arm to turn a page, you do a little work outside your body. If your pencil falls to the floor and you pick it up, you do some outside work. But the heavy thinking you do when you study does not count as work from a scientific point of view, even if you call it hard work.

In Figure 5-4 you see people doing many things. Which of them would the scientist call work?

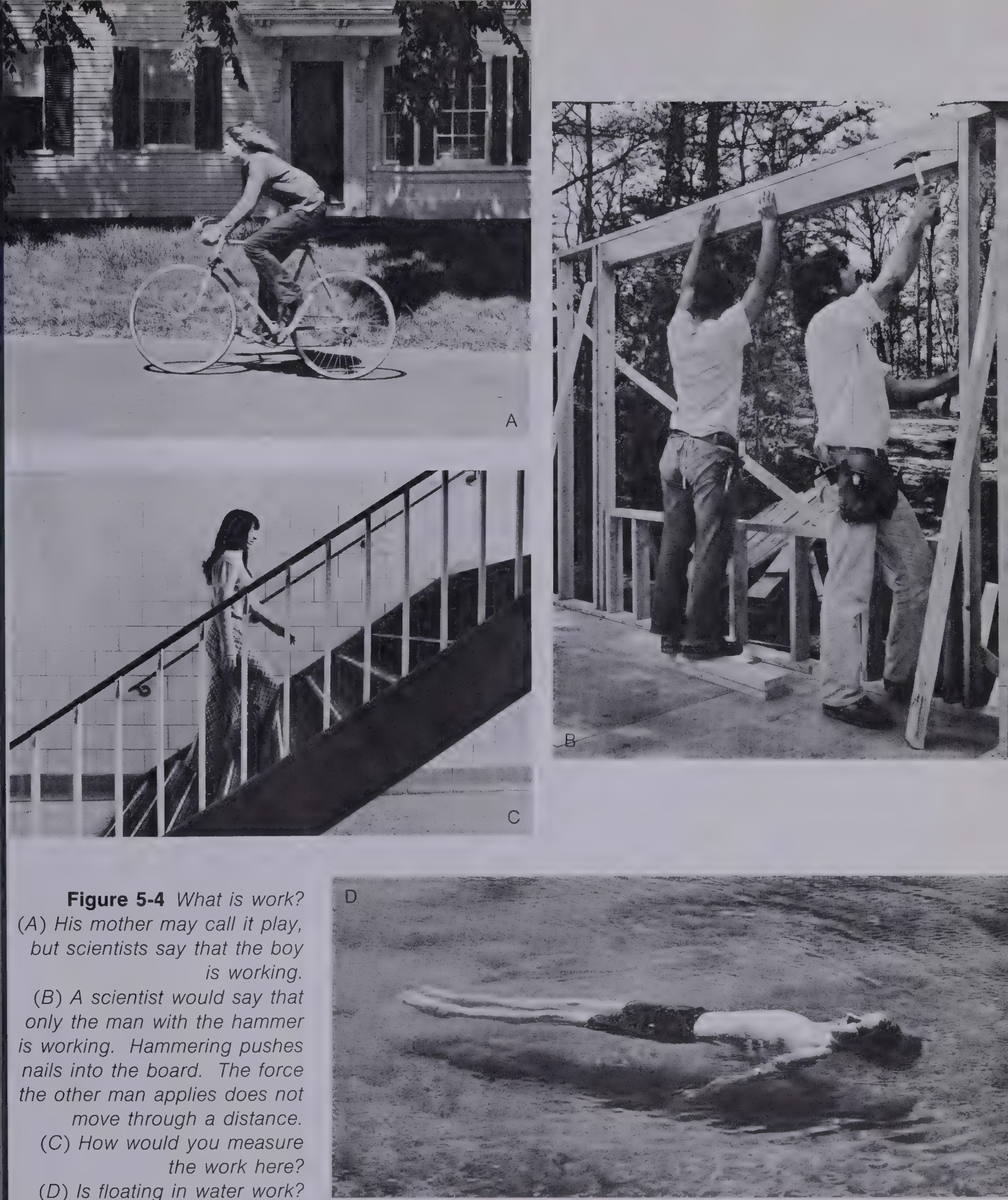


Figure 5-4 *What is work? (A) His mother may call it play, but scientists say that the boy is working. (B) A scientist would say that only the man with the hammer is working. Hammering pushes nails into the board. The force the other man applies does not move through a distance. (C) How would you measure the work here? (D) Is floating in water work?*

How much work (work input) does the girl do in Figure 5-5? What is the work output?

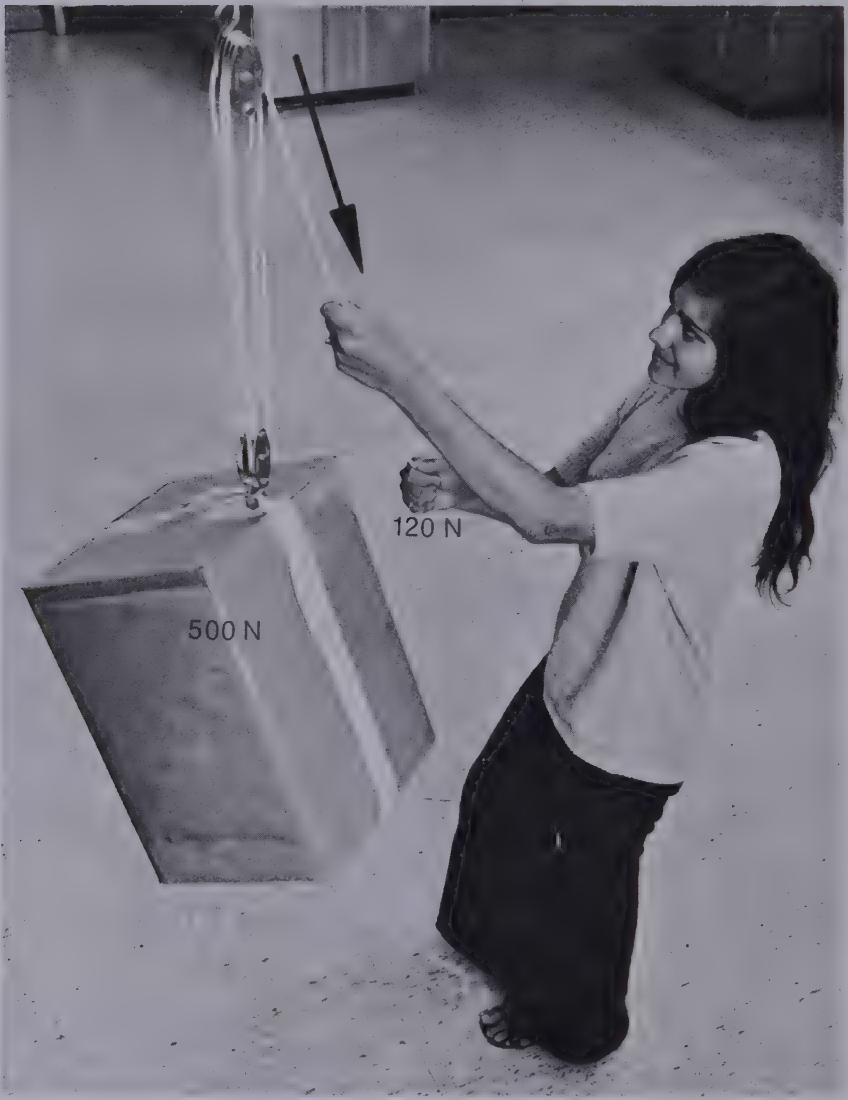


Figure 5-5 *When she pulls down 5 m of rope, the load goes up 1 m.*

5-3 Work measures energy

When you do work, you use energy. The energy comes from the food you eat. Where does the food get the energy?

Sunlight has energy. When the sun shines on green plants, the plants make sugar. The sun's energy is stored in the sugar. The plant turns the sugar into other kinds of food. Animals eat plants and store some of the food energy. You eat both plants and animals. In your body, the food combines with oxygen. Some of the stored energy becomes heat energy. Some of it becomes the energy you need to move, and to do work. **Energy** is often defined as the ability to do work.

5-4 Energy can be wasted

If you do 1000 N • m of work, you use more than 1000 N • m of energy from your food. Some of the energy is wasted. It heats you up more than you need and makes you wipe your face and go for a drink of water.

In the machines you used, the work input was more than the work output. Some of the energy that went into the machine heated up the machine and was wasted. When you made the friction less, less energy was wasted.

Other things waste energy. Look at all the machines used in the class. Make a list of ways in which the energy might be wasted. Share your ideas with the class.

If the work output of a machine is almost as great as the work input, then the machine is very **efficient** (e-FISH-ent). Which machines used in your class were quite efficient? Which were not very efficient?

Did You Get the Point?

When a small input force raises a heavy load, the input distance must be greater than the output distance.

Input distance times input force is always greater than output distance times output force.

When a force acts through a distance, the work done equals the force times the distance in the direction of the force.

Work measures the energy used to do the work.

Machines waste some of the energy that is put into them.

What Have You Learned?

1. A man uses a force of 20 N to raise a 100-N load. The load rises 1 m. What is the work output?

2. The man in Question 1 pulls down 7 m of rope to raise the load 1 m. What is the work input?

3. If someone uses a machine backwards to do something faster, what is the price he has to pay?

4. Is it ever good to have an inefficient machine?

What Becomes of the Energy You Use?

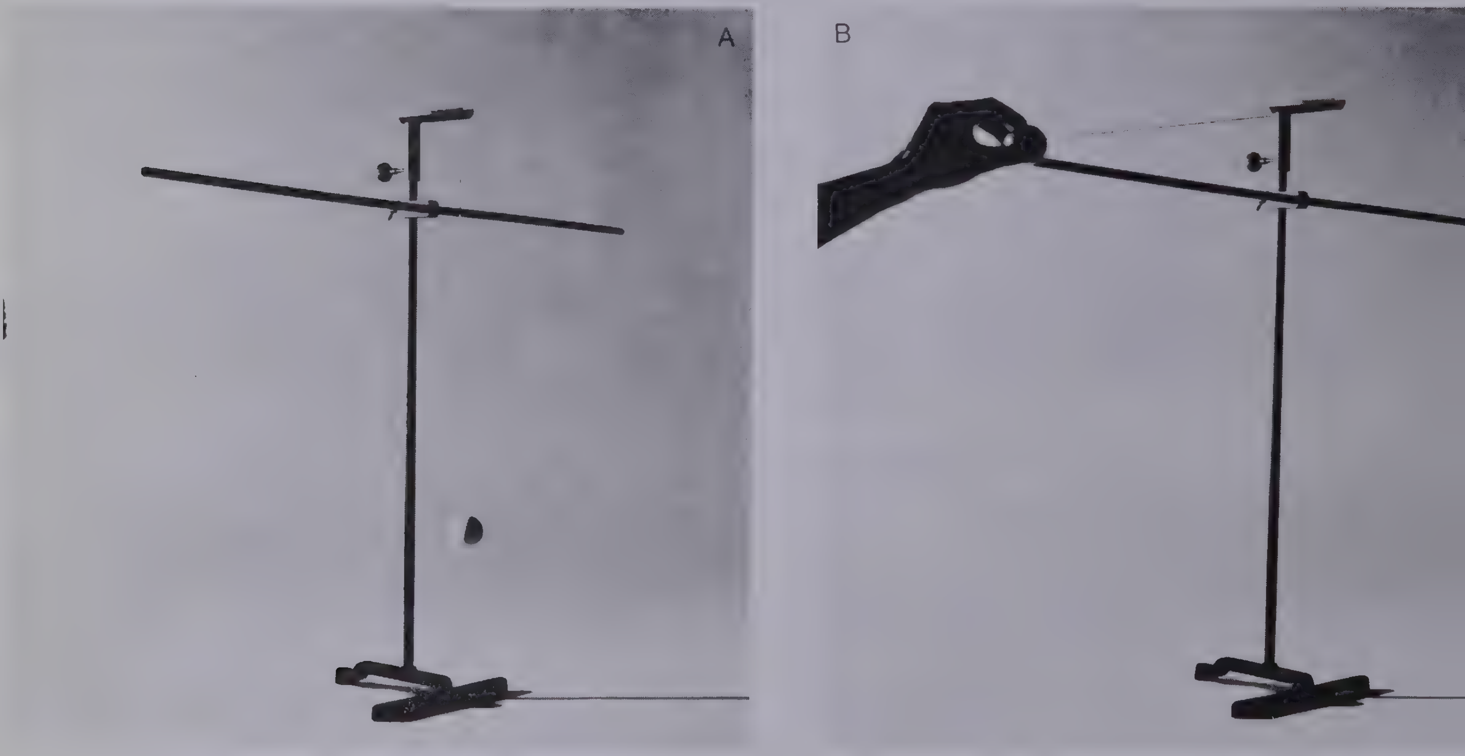
5-5 The strange behavior of a pendulum

Materials
stand, bars, clamps, string, ball, meter stick

★ Set up a pendulum like the one in Figure 5-6. Be sure the cross bar is perfectly level.

At first the pendulum is in the position shown in Figure 5-6A. Now raise the ball as shown in Figure 5-6B. Hold

Figure 5-6 *(A) Set up the pendulum like this. (B) Start the swing at the cross bar.*



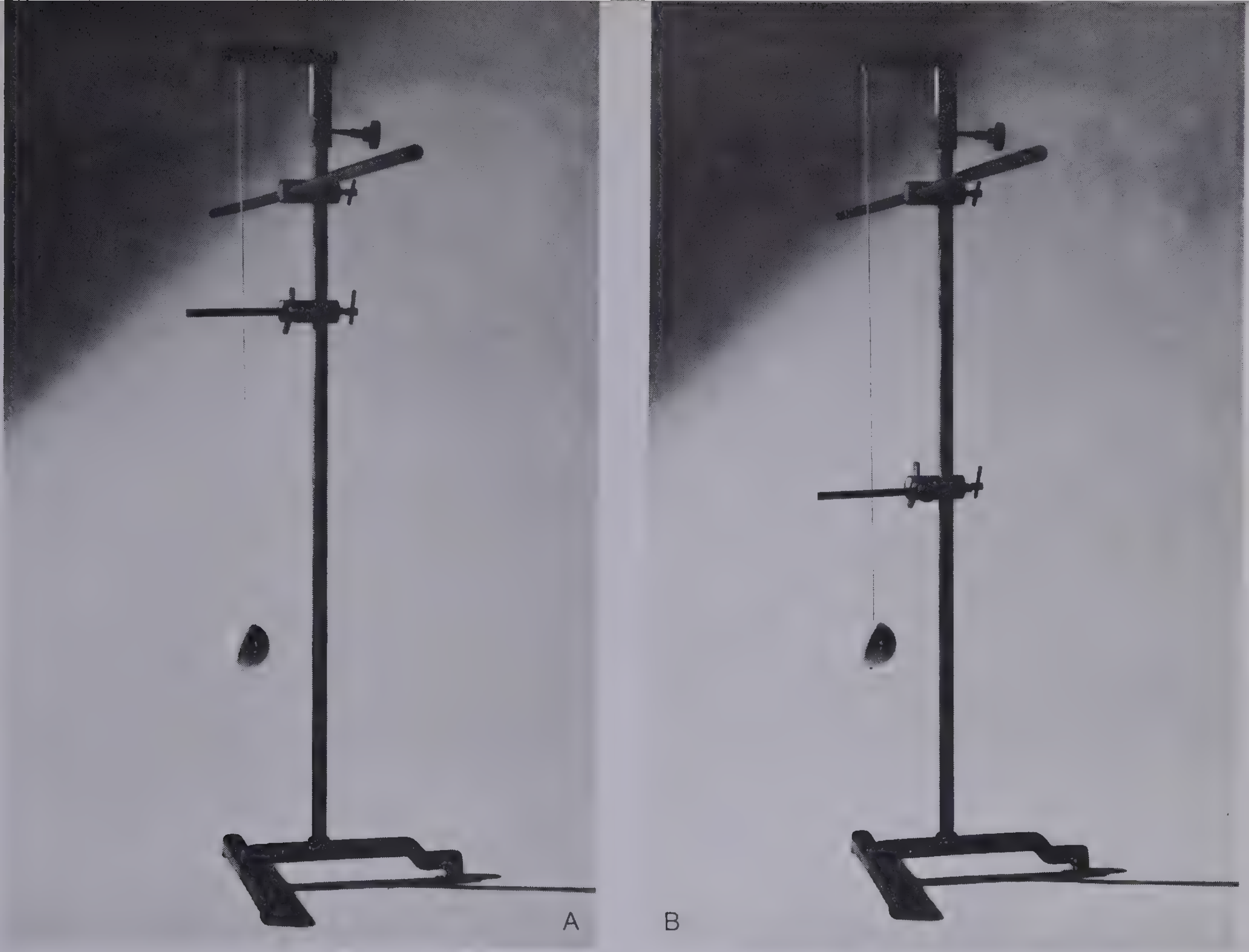


Figure 5-7 (*A*) *First put the clamp a little below the cross bar.* (*B*) *Then lower the clamp.*

the string straight. Before letting it go, make a guess about what it will do. It will swing, of course, but will it go higher than the bar at the other side, just as high, or not as high?

Next put a clamp a little below the cross bar (Figure 5-7A). The clamp must stick out enough so the string bumps into it. Guess what the pendulum ball will do. Then see what happens.

Now put the clamp down farther (Figure 5-7B). This time there is not enough string left for the ball to rise as high as the bar. What will happen?

Record your observations in your notebook. Write a summary to tell what happens (a) when there is enough string so the ball can rise at least as high as the bar, (b) when there is not enough string for this. ★

5-6 Energy can be used over and over

When someone pulls the pendulum ball up, he is doing work. In Figure 5-8 there is enough information for you to find the work. Remember that work is force times the distance measured in the direction of the force. In Figure 5-8, the force is the weight of the ball. What is the direction of the force? Does this direction change while the ball is being raised to the level of the cross bar? What is the distance in the direction of the force? If you have answered these questions correctly, you can easily find the work.

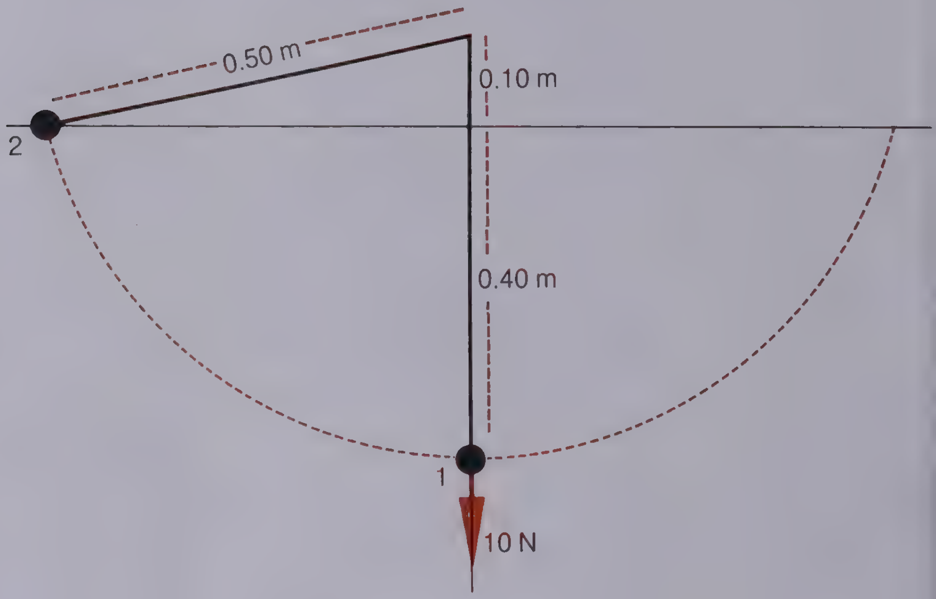


Figure 5-8 *How much work was done to lift the pendulum ball from position 1 to position 2?*

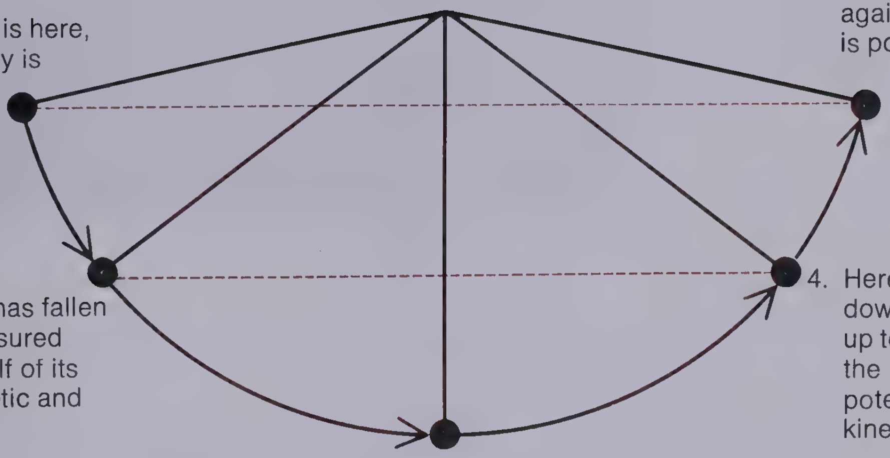
It takes energy to do work. When you raised the ball, you used energy. After that you let it go. It swung down and up the other side. It takes energy to raise the ball on the other side too. But no one was lifting it. The swing up was possible because energy really never disappears. It can be used over and over.

Here is the story of the energy of the pendulum. To lift it you used energy from the food you eat. You gave energy to the ball. While you held the ball, without letting it go, the energy was stored in the ball. It was waiting to be used.

When you let the ball go, the stored energy began to be used. It made the ball go faster and faster. When the ball reached the bottom, it was going quite fast. All of the stored energy had been turned into energy of motion.

Then the ball swung up the other side. It went slower and slower. The energy of motion was being changed into stored energy. At the top of the swing it was all stored energy. Then it swung down again. The whole thing was repeated.

Stored energy is called **potential** (po-TEN-shul) **energy.** The energy of motion is **kinetic** (kih-NET-ik) **energy.** Figure 5-9 shows the story of the energy of a pendulum.



1. When the ball is here, all of its energy is potential.
2. Now the ball has fallen halfway (measured vertically). Half of its energy is kinetic and half potential.
3. When the ball is here, all of its energy is kinetic. It is going very fast.
4. Here it has slowed down and is halfway up to the top. Half the energy is potential and half is kinetic.
5. This is as high as the ball will go. It stops before starting down again. All of its energy is potential.

Figure 5-9 *The energy of a pendulum.*

What happens when the string bumps into the clamp and is too short for the ball to reach the cross bar? It goes as high as it can (Figure 5-10). But it has not changed all its kinetic energy into potential energy. It cannot stop, because of the leftover energy. It keeps on going until it has wound all the string around the clamp.

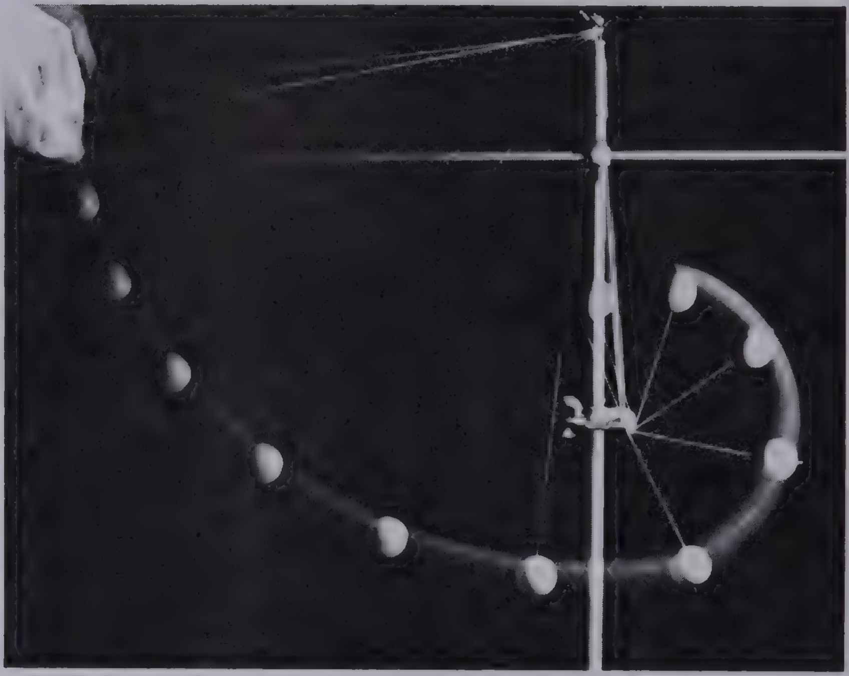


Figure 5-10 *Some of the kinetic energy of the ball has changed to potential energy. But there is still some kinetic energy left. What happens?*

5-7 Can energy be used up?

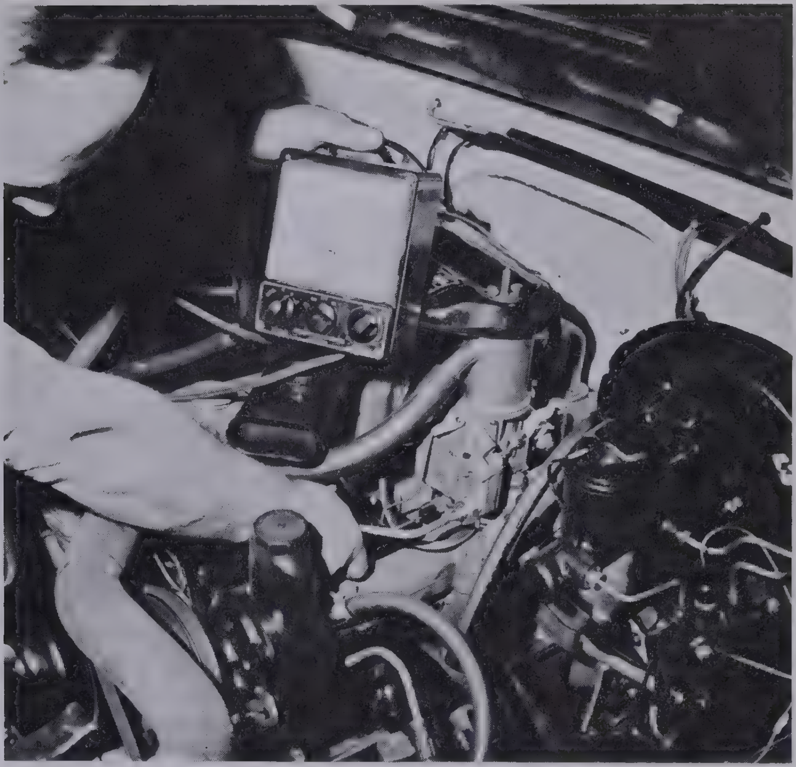
Materials
stand, clamp, string, ball

★ Let the pendulum swing again. This time do not stop it. Let it swing for a long time. Will it swing forever? ★

What happened to the energy? Some people would probably say that it is used up. But that is not true. The pendulum gave it away to other things. What other things might have received some of the energy? Make a list and discuss it in your class.

5-8 Is perpetual motion possible?

Imagine a pendulum swinging in a vacuum. There is no air to be pushed away. Imagine, too, that the support does not sway when the pendulum moves. Maybe this pendulum would go forever. The trick is to make a pendulum that



AUTOMOBILE MECHANIC

Automobile mechanics are car doctors. After an accident they make an injured automobile run again. At regular checkups they do whatever they can to keep a car running smoothly and safely. Like doctors, mechanics may do all-around repair and maintenance, or they may specialize in one kind of work. Some mechanics, for example, work only on transmissions, or only do engine tune-ups.

Mechanics use many kinds of hand tools, power tools, and electronic equipment. To keep up with changes in automobile design, mechanics must continually learn new methods and use new tools. They have to learn about new things like pollution control devices and Wankel rotary engines.

Most mechanics learn their trade on the job. They start pumping gas in a service station, or helping in a garage. They get the skills they need by working with experienced mechanics. Courses in automobile repair in high school or in a vocational school are valuable experience, too. Any background in math or science will help a mechanic understand how automobiles work.

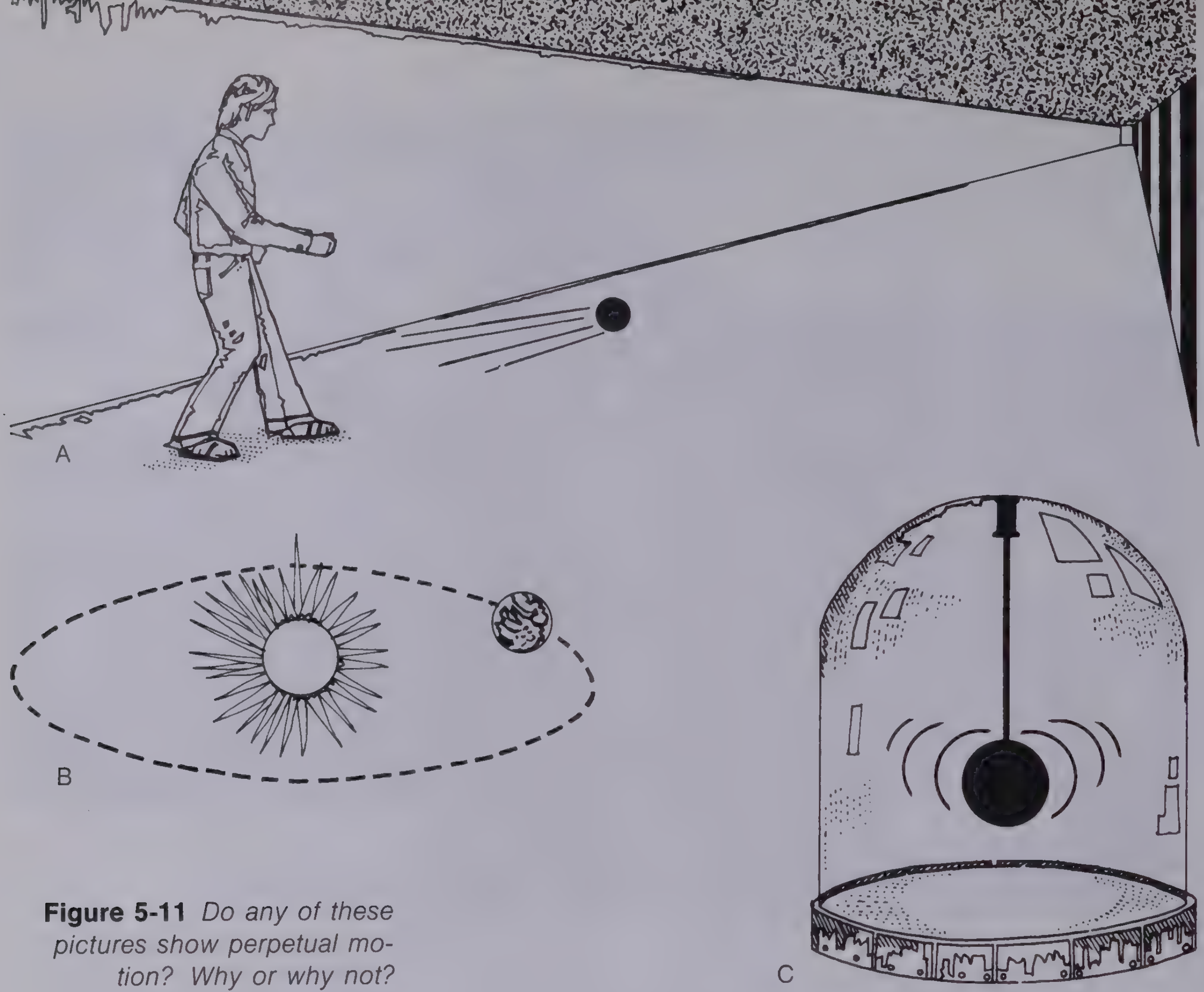


Figure 5-11 *Do any of these pictures show perpetual motion? Why or why not?*

will not give away any of its energy. Then you would have **perpetual motion.**

Can you make perpetual motion? You roll a ball on a smooth floor (Figure 5-11A). There is almost no friction, so the ball goes a long way without stopping. But friction makes the ball give its energy to other things a little bit at a time. Finally all the energy has been given away. This is not perpetual motion.

What about the earth? It has been going around the sun (Figure 5-11B) for more than four billion years. Is it giving energy away? Will it slow down and fall into the sun? If it does, that will be billions of years from now. Even this is probably not perpetual motion.

An imaginary pendulum is shown in Figure 5-11C. It is in a vacuum with no air to slow it. It does not give energy away to its support or to anything else. It will go forever. Can it be built? No one knows, but we can imagine it.

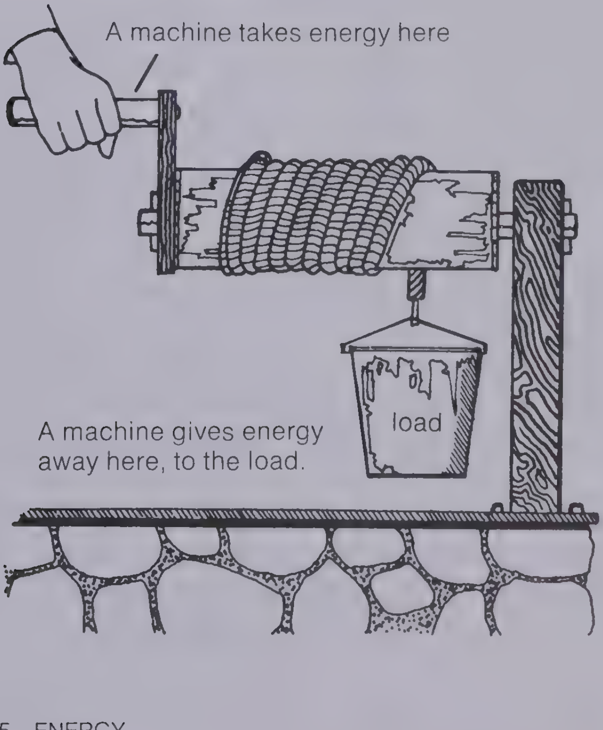
A person can imagine perpetual motion. Can you also imagine a perpetual motion machine?

First of all, just what is a machine? A machine takes energy in (work input) and gives energy away (work output). In Figure 5-12, how does energy get into the machine? What happens to it? If the machine had no friction at all, the work input and work output might be equal. You know that this is not very likely. But at least you can imagine it.

Now imagine that the man in Figure 5-12 starts his machine with a good push. This gives the machine some energy. The machine gives the energy to the load. The load rises. Now the man stops pushing. The machine has no more energy to give to the load. It has to stop.

The people who imagine **perpetual motion machines** want something that will give away energy forever. That is impossible. If it gives away energy, it has to stop, unless something feeds it new energy. A perpetual motion machine is as impossible as a gum machine that gives out gum forever without being refilled.

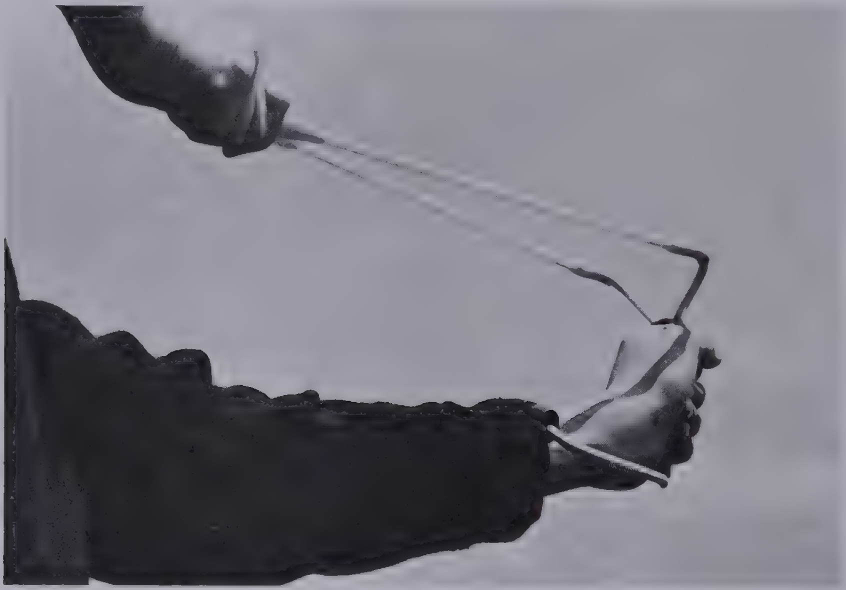
Figure 5-12 *What happens to the energy that is put into this machine?*


A machine takes energy here
load
A machine gives energy away here, to the load.

5-9 Sometimes energy seems to disappear

A boy pulls back the rubber band of a slingshot (Figure 5-13). He has to use a force through a distance. He does work. What happens to the energy he uses? Think back to the experiment with the pendulum. It will help you with the answer. Think also what happens to a pebble in the slingshot when he lets it go.

Figure 5-13 *Which part of a slingshot stores energy?*



Sometimes energy seems to disappear. When you use a machine, the work output is always less than the work input. What happens to the missing energy?

Materials
ribbon

★ Here is a simple experiment that will help you to find the answer. Take a piece of strong ribbon. Touch it to your lips. Then rub it hard about 10 or 12 times on the edge of a table. Finally touch the rubbed part to your lips again. What do you notice? What has happened to the work you did when you rubbed the ribbon? ★

Heat is a form of energy. Whenever there is friction, some of the work changes to heat. You have probably noticed times when work is changed into heat energy. See how many you can remember. If possible, bring something to class that will show a change of work into heat energy.

Whenever energy seems to disappear, see if it might have changed into heat energy. Think about your machines. The work input was greater than the work output. Could the missing energy have changed to heat?

There are many kinds of energy. Some other forms of energy are heat energy, sound energy, electric energy, and light energy.

Energy never really disappears. It only changes from one form to another. This idea is called the **law of conservation of energy.**

Did You Get the Point?

Energy is never lost.

Energy can be stored.

Energy can change from one form to another.

What Have You Learned?

1. If you lift a 60-N rock 2.0 m high, how much work do you do? What becomes of the energy?

2. You drop the rock of Question 1. When it has dropped 1.0 m, how much kinetic energy does it have? How much potential energy?

3. When a batter hits a home run, he gives the ball both kinetic and potential energy. Explain.

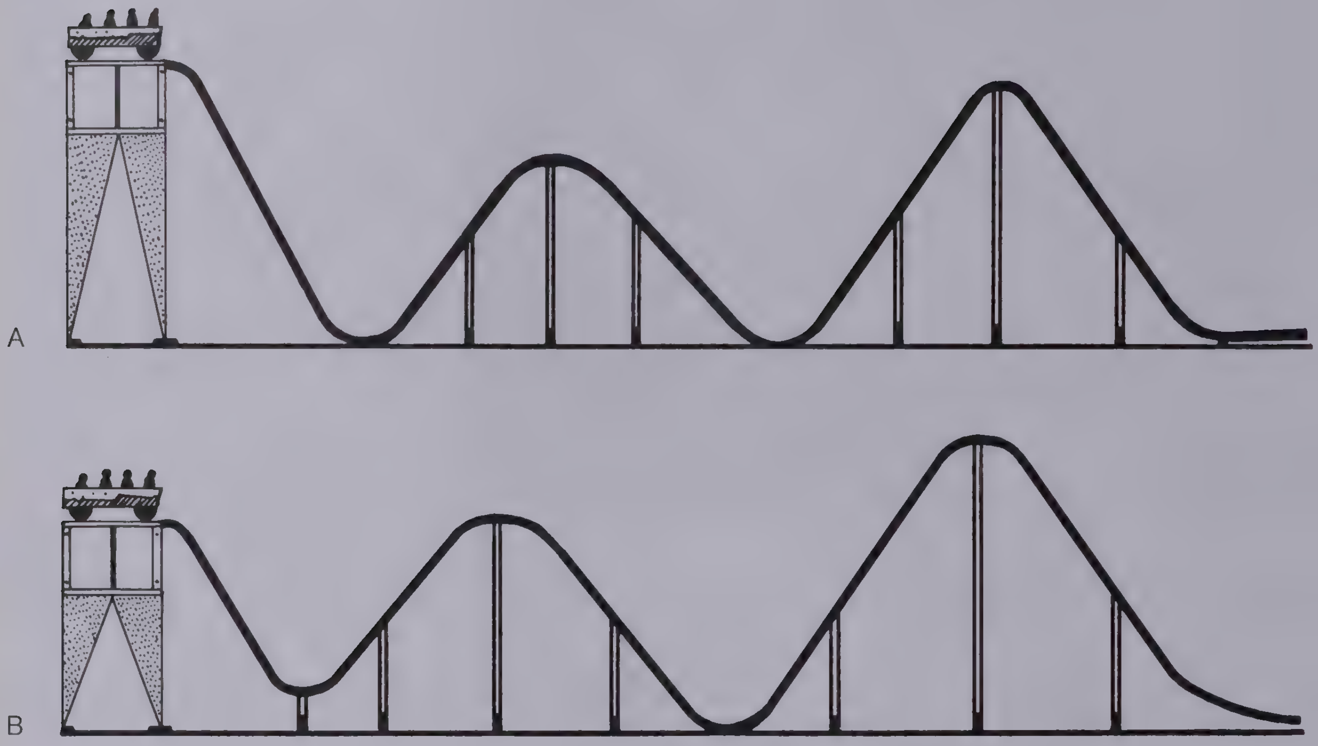
4. A batter thought he was hitting a home run. Instead a fielder caught it just inside the fence. What happened to the energy the ball had just before it was caught?

5. In one of your experiments with the pendulum, the string wound round and round the clamp. Why did it do this? What became of the energy that the pendulum had?

SKULLDUGGERY

1. The cars in the roller coasters (Figure 5-14) are hauled to the top of the first hill by a motor. There they are let go and are supposed to travel to the end with no help from a motor. Only one of them will work. Which one? Why?

Figure 5-14 *Roller coasters for Skullduggery Question 1.*



2. What is wrong scientifically with the water mill on page 90?

3. When people say someone is an efficient person, does the word "efficient" mean the same as it does in this chapter?

4. When people steal things from stores, they think they are getting "something for nothing." But are they? Who ends up paying the bill: the person who owns the store, the people who work in the store, or the people who shop in the store?

FOR FURTHER READING

Adler, Irving. *Energy.* New York: The John Day Company, Inc., 1970. Deals with energy in its many forms.

Hinkelbein, Albert. *Energy and Power.* New York: Franklin Watts, Inc., 1971. Describes sources of energy, new ways of using energy, and speculation on its future supply.

Millard, Reed, and Science Book Associates Editors. *How Will We Meet the Energy Crisis; Power for Tomorrow's World.* New York: Julian Messner, 1971. Presents alternative solutions to the need for more power to run our labor-saving devices.

Ross, Frank. *The World of Power and Energy.* New York: Lothrop, Lee and Shepard Co., Inc., 1967. Includes sun, wind, water, oil, and chemical and atomic power.

WHAT'S NEXT?

In winter you walk across a rug. You touch a doorknob. A spark jumps. You have changed some of the kinetic energy of your walking into electric energy. How does this work? You will learn about electric energy in the next unit.

Unit Three

Electric Energy

Chapter 6

Electric Charges

Does lightning ever strike twice? It certainly does. The Empire State Building in New York City is hit by lightning many times each year. Lightning goes toward tall things, and this building is one of the tallest in the world.

But no one gets hurt when lightning strikes the Empire State Building. How is this possible? Just what is lightning anyway? You will find answers in this chapter.

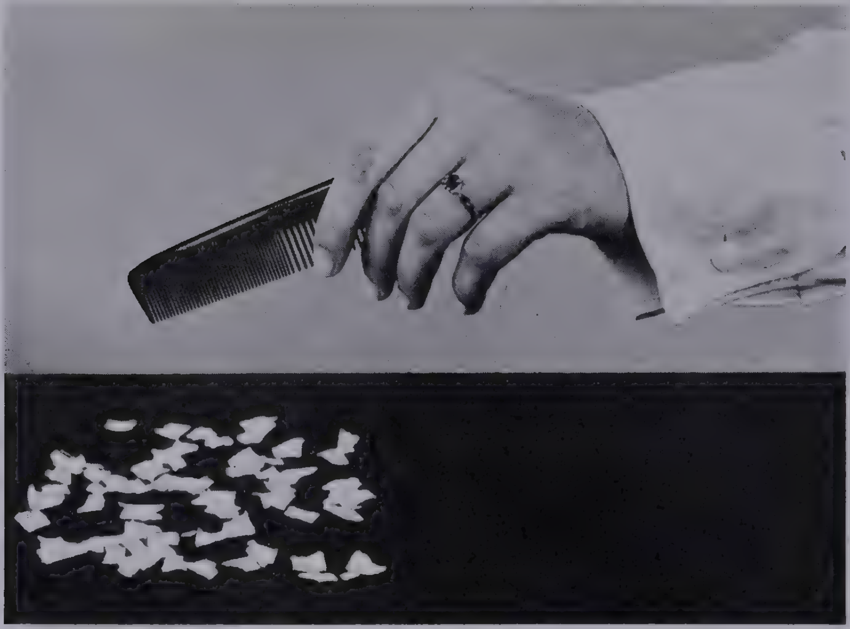


Figure 6-1 *If the comb is charged, what will happen here?*

Kinds of Electric Charge

6-1 Charging things

If you want to find out about lightning, you have to start with charges.

Materials
paper, plastic comb or pen

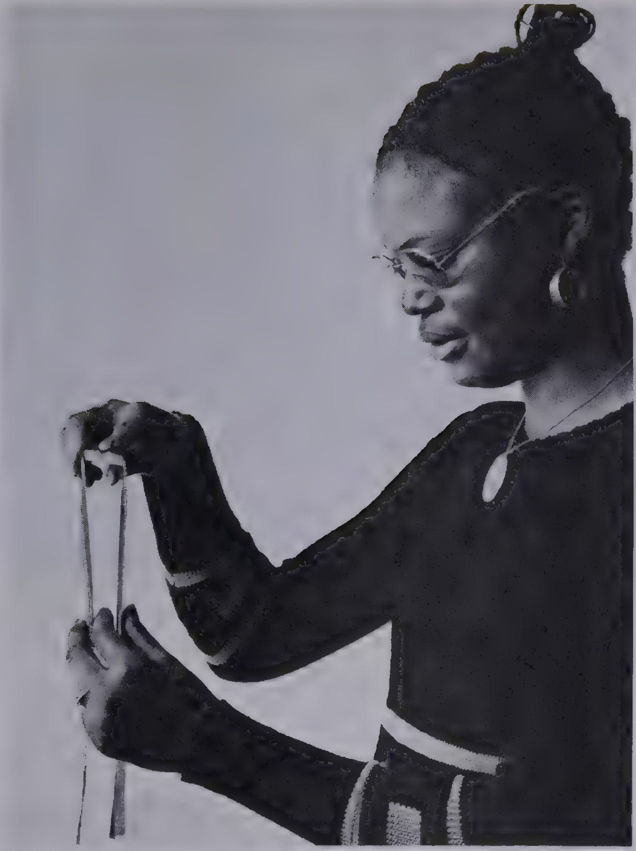
★ Try a very simple experiment right now. Tear off a few tiny pieces of paper. Put them in a pile (Figure 6-1). Take your comb or a plastic pen or pencil and rub it hard in your hair. Touch it to the pile of paper. What happens?

Here is a simple definition of charged things. Something becomes **charged** if (1) you rub it and then (2) it picks up something that has not been rubbed.

For homework, try rubbing all sorts of things together. Then see if they can pick up bits of paper or thread. Bring to class the things you can charge. ★

6-2 How do charged things behave?

Charged objects behave in ways that might surprise you. In this experiment you will discover what they do.



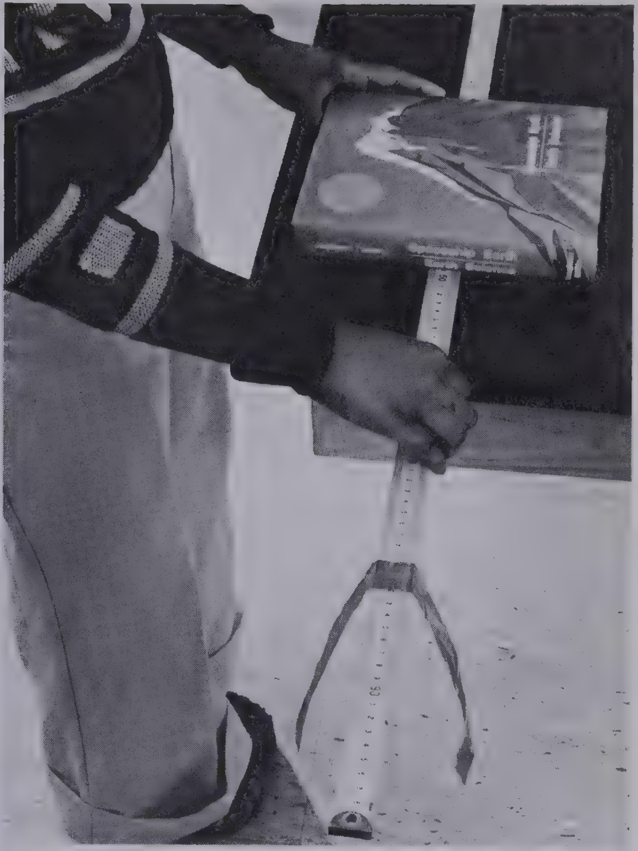


Figure 6-2 (*left*) *How to charge a vinyl strip.*

Figure 6-3 (*right*) *How can you tell that the strip is charged?*

Materials
vinyl plastic strip, fiberglass strip, plastic sheet, long wooden stick, short wooden stick

★ Rub a narrow vinyl (vı-nil) plastic strip with your hand. Will it pick up pieces of paper? Is it charged?

Now fold it in two. Hold it at the fold so that the ends hang down. Rub it by running the other hand quickly down, as in Figure 6-2. Do this two or three times. When you hold the folded strip up, what do the two ends do?

Hang the strip on a long stick, as shown in Figure 6-3. Do not hang the strip too close to the table. The ends may stick to the table.

Cover your hand with a sheet of vinyl plastic. Rub a folded strip of fiberglass with the plastic. Fiberglass is woven from thin glass threads. Is the fiberglass charged? Test it. Hold the fiberglass up, letting the ends hang down. What do the ends of the strip do?

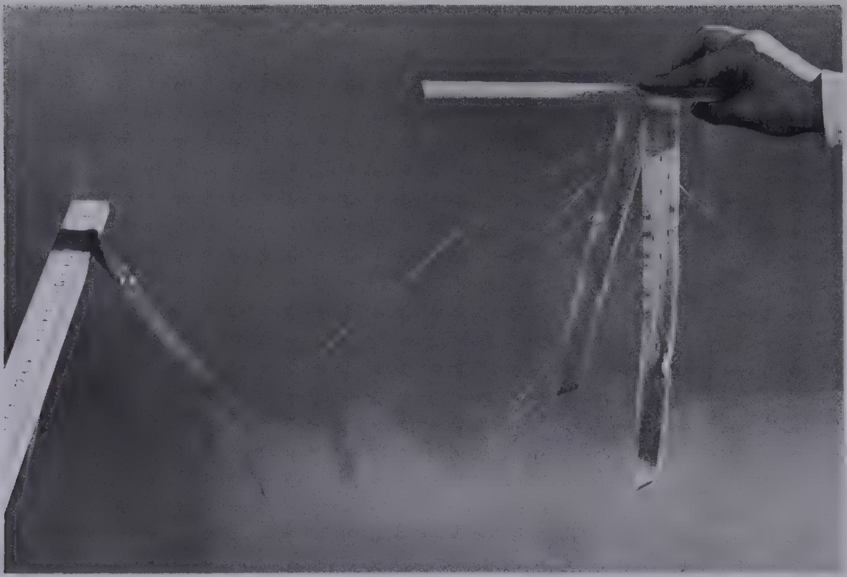


Figure 6-4 *Does the fiberglass strip attract or repel the vinyl strip?*

Hang the fiberglass strip on a wooden ruler (Figure 6-4). Carefully bring it near the hanging vinyl strip. Do not let the fiberglass touch the vinyl. What do you observe?

Leave the vinyl strips hanging on their stick. Charge other objects by rubbing and bring them near the charged vinyl. Notice whether they attract or repel the strips. **Repel** means to push away.

Record your observations in complete sentences in your notebook. The sentences should be like these: ''Two pieces of vinyl plastic rubbed by my fingers (attracted, repelled) each other. A piece of fiberglass rubbed by vinyl (attracted, repelled) vinyl plastic rubbed by my fingers.''

Discuss your observations in class. What interpretations can you make? ★

6-3 Positive and negative

Benjamin Franklin, before the American Revolution, did experiments like yours. He found that two charged glass rods repelled each other. Then he found that a charged hard rubber rod attracted a charged glass rod. (Vinyl plastic had not yet been invented.) He made interpretations, just as you did. He decided that the charge on the glass was different from the charge on the rubber.

Franklin also discovered a rule about charges. It is the same one you discovered: **Charges that are the same repel. Charges that are different attract.**

Franklin had a hypothesis about what happened when he charged the rods. He suggested that everything contained an electric fluid. He guessed that his glass rods took fluid away from what he used to rub them. This gave them extra fluid, so he said they were positive (+). He thought rubber rods lost fluid when they were rubbed. Therefore he called them negative (−).

Franklin did not really know what caused the charges. He simply made a good guess. What he did know was that the charge on the glass was different from the charge on the rubber. He could have given them other names, but he chose *positive* and *negative.* They have been called that ever since.

In your class, you can use these definitions: **Positive** electric charge (+) is the kind of charge on fiberglass when you rub it with vinyl plastic. **Negative** electric charge (−) is the kind of charge on vinyl plastic when you rub it with your hand.

Make a table like Figure 6-5. Write in it the kind of charge on each thing you tested. The things mentioned in the last paragraph are shown in the table. The sentences you wrote in your notebook will give you information. Use your hanging plastic strips if you are not sure.

Figure 6-5

Charged object	Rubbed by	Kind of charge
vinyl strips	hand	negative
fiberglass	vinyl plastic	positive

6-4 Where do charges come from?

Materials
vinyl plastic strip, fiberglass strip, plastic sheet, long wooden stick, short wooden stick

★ Charge the vinyl strip. Hang it up as you did before (Figure 6-3).

Next, be sure the fiberglass and the vinyl plastic around your hand have no charge. The best way to do this is to

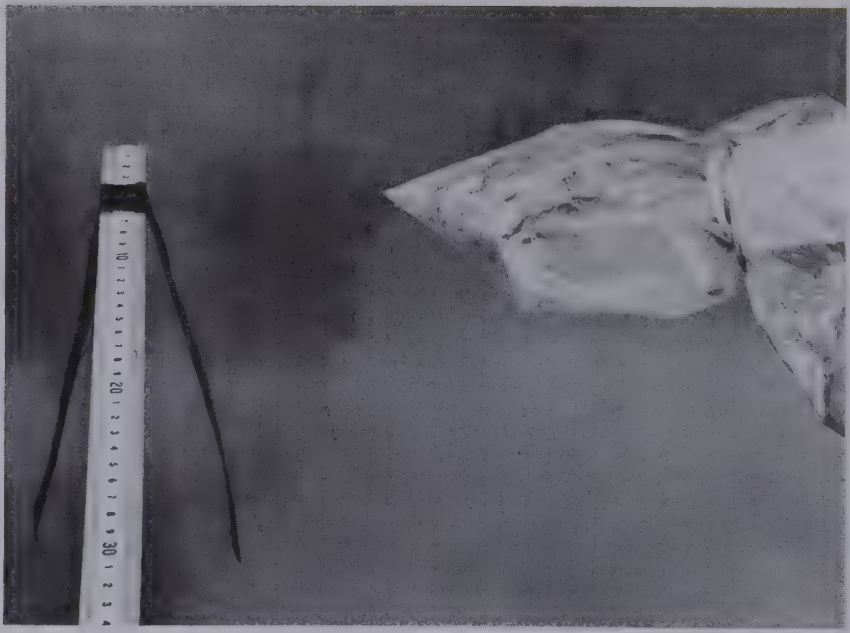


Figure 6-6 *What happens when the plastic sheet comes near the charged vinyl strip?*

touch them to a gas or water pipe. You must touch all of the object to the pipe, not just a part of it. This method of getting rid of a charge is called **grounding.**

Now use the plastic sheet to charge the fiberglass. Find out what kind of charge is on each of them by testing with the hanging strips (Figure 6-6). What do you observe? ★

At the beginning, both the vinyl and the fiberglass were neutral. The word **neutral** means "without a charge." Now they both have charges, opposite ones. Where did these charges come from? They must have come from the materials you rubbed.

Scientists have a way to explain your observations. They say that all materials contain tiny particles. Some are positively charged. Some are negatively charged. The tiny positive particles are called **protons.** The tiny negative particles are called **electrons.** When something is neutral, it has just as many protons as electrons.

Most things are neutral. Therefore, an object usually has equal numbers of protons and electrons (Figure 6-7). If you rub two things together, one may take electrons from the other. Now they both have charges. In solids, the electrons move, not the protons. It is impossible to get a positive charge by rubbing unless you get a negative charge at the same time.

In Section 6-1 you had a definition for *charged.* Here is a better one: An object is **charged** if it has unequal numbers of protons and electrons.

The idea that there are protons and electrons is a theory. A **theory** is a suggested explanation. This theory works so well that scientists believe it is true. No one has ever seen electrons and protons. But by believing in electrons and protons, scientists can explain electric current in wires, and lightning, and why gasoline burns, and how you get energy from food.

6-5 What happens when charged objects meet neutral ones?

Materials
vinyl and fiberglass strips, plastic sheet, paper

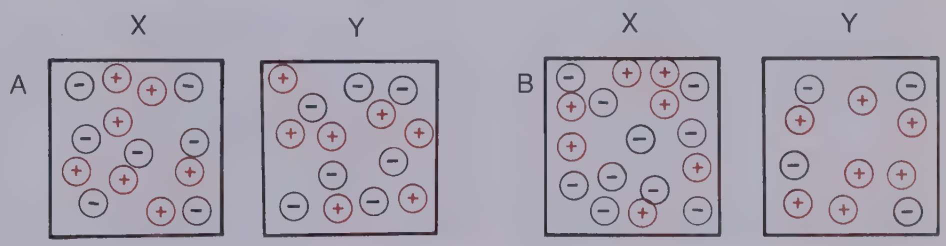
★ Ground a small piece of paper. Then tear it into tiny bits. Make two piles of the paper, not close to each other. Charge a vinyl strip with your hand. Will it pick up some of the paper from one pile? Do not let it touch the other pile.

Now charge the fiberglass strip. Will it pick up paper from the other pile?

Write your observations in your notebook. Then write a summary to tell what happens when a charged object meets a neutral one. ★

How can the theory about electrons and protons be used to interpret your observations? Discuss this in your class. Write the interpretation in your notebook.

Figure 6-7 *(A) X and Y are both neutral objects. Each one has just as many protons (red) as electrons (black). (B) When they are rubbed together, some electrons go from Y to X. The extra electrons make X have more negative charges than positive charges. Y has more positive than negative charges.*



Did You Get the Point?

All matter contains positively (+) charged particles called protons and negatively (−) charged particles called electrons.

Charges that are the same repel. Charges that are different attract.

An object is neutral if it has equal numbers of electrons and protons. Most objects are neutral.

When objects are rubbed together, electrons may move from one to the other. This charges both objects.

What Have You Learned?

On a separate sheet of paper, write the missing words in this paragraph. If you do it correctly, the last letter in each missing word will be the first letter of the next missing word.

The ____ is a tiny positive charge. A tiny ____ charge is the ____. An object with equal amounts of these two kinds of charge is ____. If two charges are not ____ each other they attract. When you rub things together, ____ charges from one may move to the other. Then both objects are ____. Each one has a ____ kind of charge. The idea that there are tiny electric particles in all matter is called a ____.

Electric Fields

6-6 Charges are surrounded by electric fields

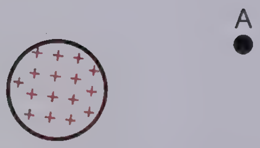


Figure 6-8 *The large round object has lost electrons. It has a strong positive charge.*

Imagine an electron at A in Figure 6-8. What would it do? What would a proton at A do?

A proton is repelled by an object with a positive charge. The closer they are, the stronger the force. If they are far apart, the force becomes very small, but it is still there. The space around the big charged object in Figure 6-8 is called the **electric field** of that object. The field is strong near the object. It is weaker farther away, but never zero.

Materials
copy of Figure 6-9

★ Your teacher will give you a copy of Figure 6-9. Follow the directions. The arrows you draw show the direction of the field. The **direction of an electric field** is the direction of the force on a positively charged particle in the field. ★

Imagine an electron at each of the points in your diagram. Will it move in the direction of the arrows? Will the length of the arrow tell you about the size of the force?

6-7 Electroscopes explore electric fields

An electroscope is shown in Figure 6-10. Compare it with the one in your class. Here are some experiments to do with the electroscope. Think about the questions, but do not write the answers yet.

Materials
electroscope, vinyl strip

★ 1. Charge a vinyl strip negatively. Bring it near the electroscope knob. Do not let it touch the knob (Figure 6-11). What happens as the vinyl comes closer to the

Figure 6-9 *Write on your copy, not in the book.*

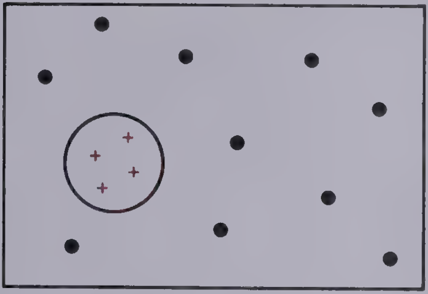


Figure 6-10 *Your electroscope may not look exactly like this one, but it will have these parts: (1) a metal knob on top; (2) a metal rod connected to the metal knob; (3) one or more lightweight pieces of metal connected to the other end of the rod. These are called leaves. Ground the knob before you begin. Then you know it is neutral.*

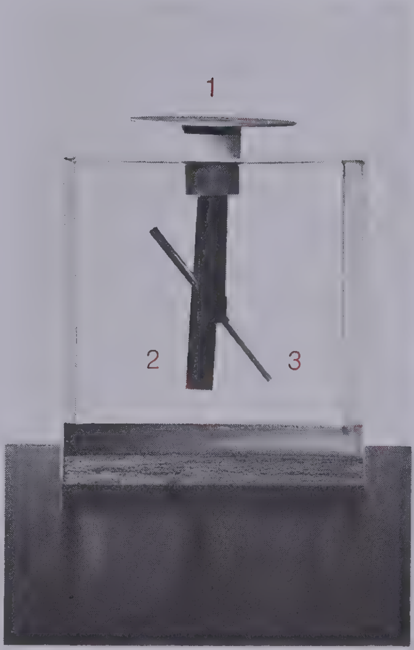
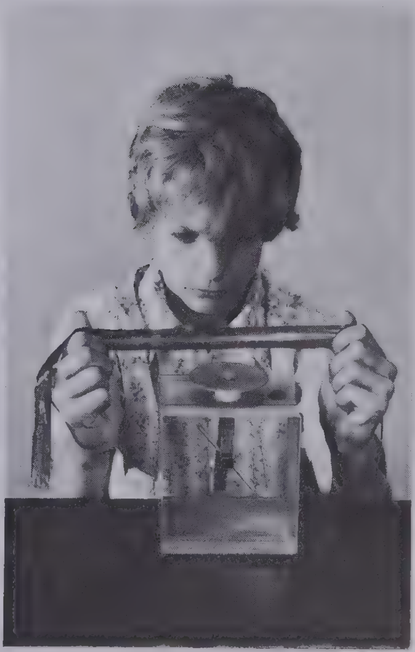


Figure 6-11 *Hold the vinyl strip about 2 or 3 inches above the knob.*



knob? What happens when it moves away? Use the electron theory to explain why these things happen.

2. Repeat the experiment. This time listen carefully. If electrons jump across to the electroscope you will hear a tiny crackle. In the dark, you would see a spark. What happens if you move the vinyl away before there can be a spark? What happens if you move it away after there is a spark or the vinyl touches the knob?

3. Touch the negative vinyl to the knob. Try to put enough charge on the electroscope to make the leaves go halfway out. Why does this charge the electroscope? If you have too much charge, take some off by touching the knob with your finger. Why does this remove some charge?

4. Bring a negatively charged strip near the knob of the charged electroscope. What happens? Take away the vinyl. Bring a positive fiberglass strip near the knob. What happens? Ground a pencil. Bring it near the knob. What happens? Explain why each of these things happens.

A charged electroscope will tell when something else is charged. It also tells whether the charge is positive or negative. This makes the electroscope very useful.

Summarize your observations and interpretations, using Figure 6-12 and the following questions.

A. The electroscope is neutral. You bring a strip with a negative charge near it. What do the leaves do? Why?

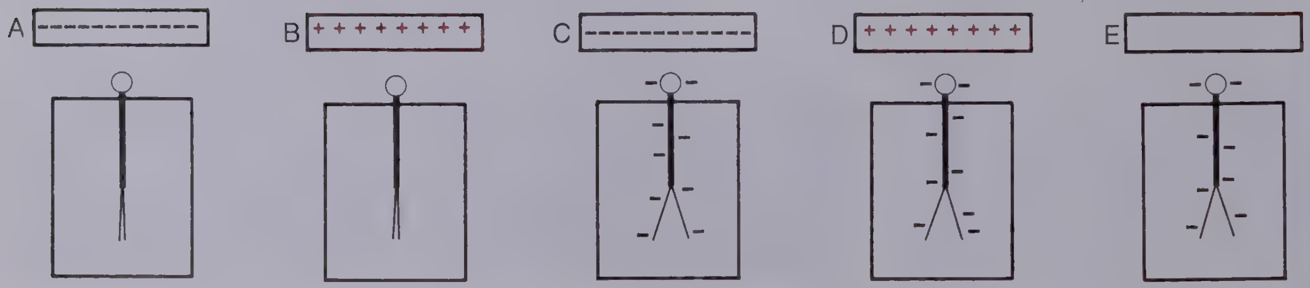
B. The electroscope is neutral. You bring a strip with a positive charge near it. What do the leaves do? Why?

C. The electroscope is negative. You bring a strip with a negative charge near it. What do the leaves do? Why?

D. The electroscope is negative. You bring a strip with a positive charge near it. What do the leaves do? Why?

E. The electroscope is negative. You bring a pencil with no charge near it. What do the leaves do? Why? ★

Figure 6-12



6-8 Conductors and insulators

Materials
electroscope, comb

★ Charge an electroscope part way. Ground your comb and test it with the electroscope. If it is not neutral all over, ground it again. Ground your hand too.

When you are sure that your hand and comb are neutral, comb your hair rapidly. Now test your comb with the electroscope. Is it charged at the end that did the combing? Is it charged at the other end? ★

The comb has extra electrons after you have combed your hair. Each electron repels other electrons. But the electrons cannot move to the other end of the comb. Materials, like that of your comb, that keep electrons from moving are called **insulators** (IN-suh-lay-ters).

Now look at the electroscope. The knob is made of metal. So is the rod and so are the leaves. If you touch the knob of a neutral electroscope with a charged comb, electrons quickly run down to the leaves. Materials, like this metal, that let electrons move, are called **conductors** (kon-DUCK-ters). A good conductor is a bad insulator. A good insulator is a bad conductor.

All metals are good conductors. Plastics, rubber, glass, and wood are good insulators. Perfectly pure water is an insulator. But if salt is added to it, it becomes a conductor. Water from a faucet is not a very good conductor, but it is a better conductor than perfectly pure water.

6-9 It takes work to separate charges

In Figure 6-13A two charges are attracted. They cannot neutralize each other because of the insulator. In Figure

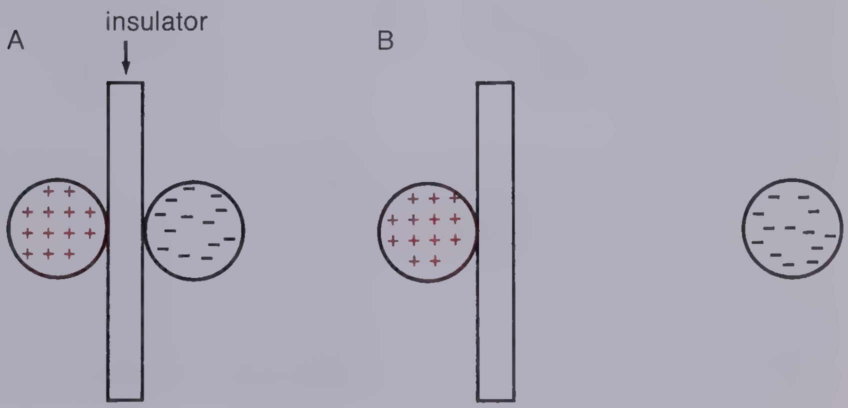


Figure 6-13 (*A*) *What would happen if the insulator were taken away?* (*B*) *Did it take work to move the negative charge?*

6-13B the negative charge has been moved. Was a force needed to make it move? Why? In what direction? What do you need to know to find the work that was done to move the charge?

It takes energy to do work. But energy never disappears. What happened to the energy in Figure 6-13?

Figure 6-14 shows an electrostatic machine. A motor inside the machine turns a belt that goes up into the large knob. The motor uses a force to turn the belt. It does work. Charges are separated. One round knob becomes positive, the other negative. These charges have potential energy. Soon electrons jump from the negative knob to the positive one. They change potential energy into kinetic energy of motion. They change potential energy into at least three other kinds of energy too. What are they?

The spark looks like lightning. That is exactly what it is, a very tiny lightning stroke (Figure 6-15).

Because separated charges have potential energy, people say there is a **potential difference** between them. Potential difference is measured in **volts.** If you get a spark an inch long in air, the potential difference is probably over 30,000 volts.

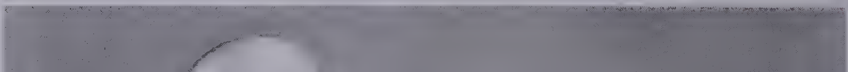


Figure 6-14 *The round knobs have different charges because inside the machine different materials are rubbing together very fast. How is this similar to the way you charged the vinyl strip?*

6-10 You can make lightning

Materials
old record, wool cloth, nylon jersey, aluminum pan, thumb tack, pencil

★ Here are ways to make tiny lightning strokes. They work better on dry days than on damp ones. They work best at home at night with the lights out.

1. Put an old record (one you don't mind scratching) on a table. Rub it with a wool cloth. Pick it up. You will hear it crackle. In the dark you will see what looks like sheet lightning.

2. Fold a piece of nylon jersey (underwear or a shirt). Rub it on the edge of a table, holding it stretched. You will hear a crackle. In the dark, you can see sheet lightning.

3. Push a thumb tack up through the middle of a thick aluminum pan (from a frozen pie, for example). Stick it into

Figure 6-15 *Lightning does not always look the same. (A) Lightning can jump from one cloud to another. (B) Sheet lightning is really lightning reflected from clouds.*

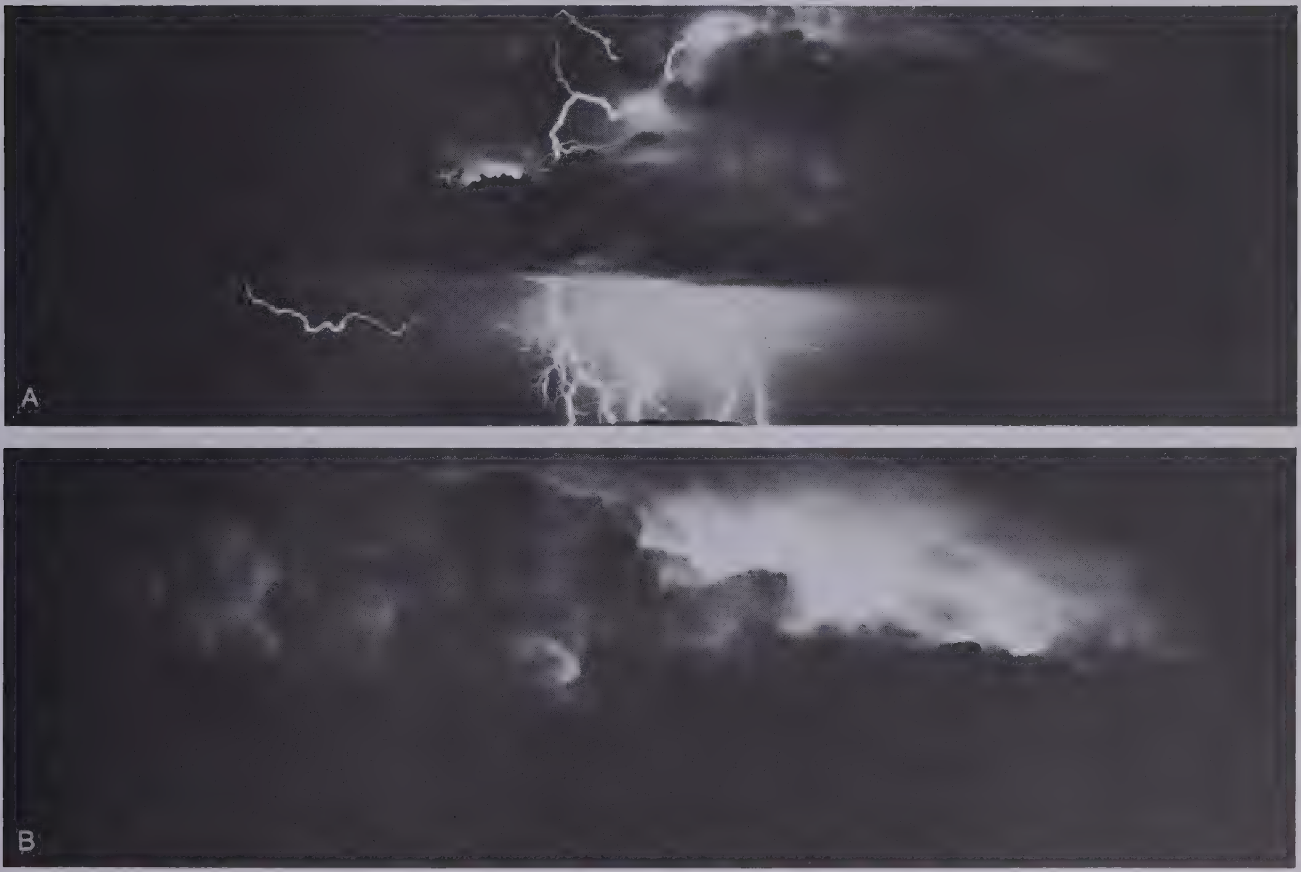
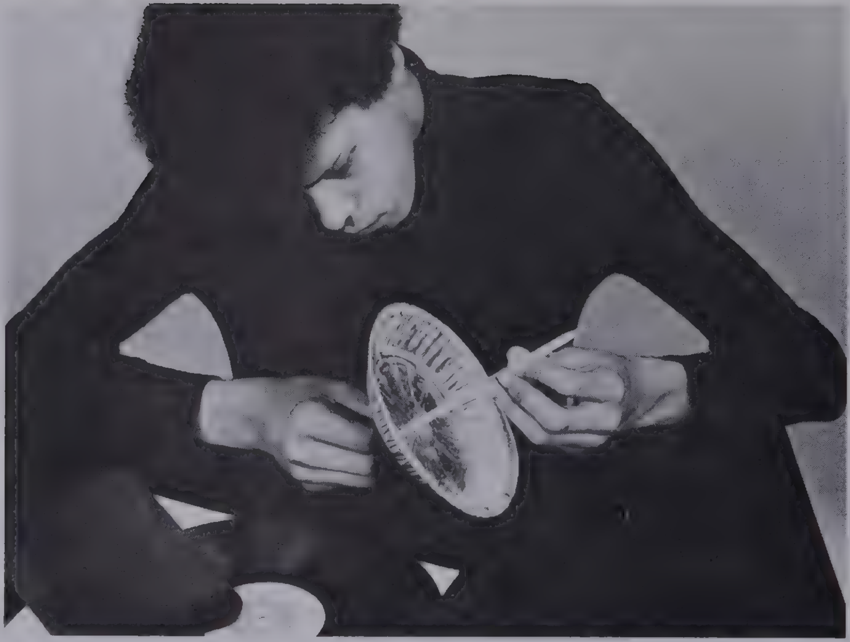


Figure 6-16 *A thumb tack sticks through the pan from the bottom and holds the pencil.*



the eraser of a pencil to make a handle (Figure 6-16). Rub an old phonograph record with a wool cloth. Do not pick up the record. Instead, put the aluminum pan in the middle of it. Put one of your hands on the pan. After you take your hand away, pick up the pan with your other hand, using the pencil handle. Now slowly bring the hand that was touching the pan back near the pan. You will hear a spark. In the dark it will look like a tiny lightning stroke.

4. Rub your feet on a rug in a warm house when it is cold and dry outside. Then shake hands with a friend or touch a water faucet. You may feel and hear a spark.

In all of these activities you have used friction to separate charges. Then you have let electrons jump a gap. During a storm, enormous numbers of electrons also jump a gap to make the lightning. ★

6-11 How to protect yourself from lightning

Study Figure 6-17 to learn about lightning. Lightning is dangerous. Follow these rules for safety.

1. Stay indoors during thunderstorms.
2. Stay away from open windows and doors.

3. Do not touch metal pipes, including water faucets. Stay out of the bathtub. Do not use any plug-in electric appliance like a television set or an iron.

4. If you are outdoors, stay away from tall trees or poles or power lines.

5. If you are in an open field, you are the tallest thing around. Lie down if you cannot get away fast. Lie down immediately if you feel your hair stand on end. This means you are charged. Each hair is repelling the next one.

6. If you are in a boat, get to land.

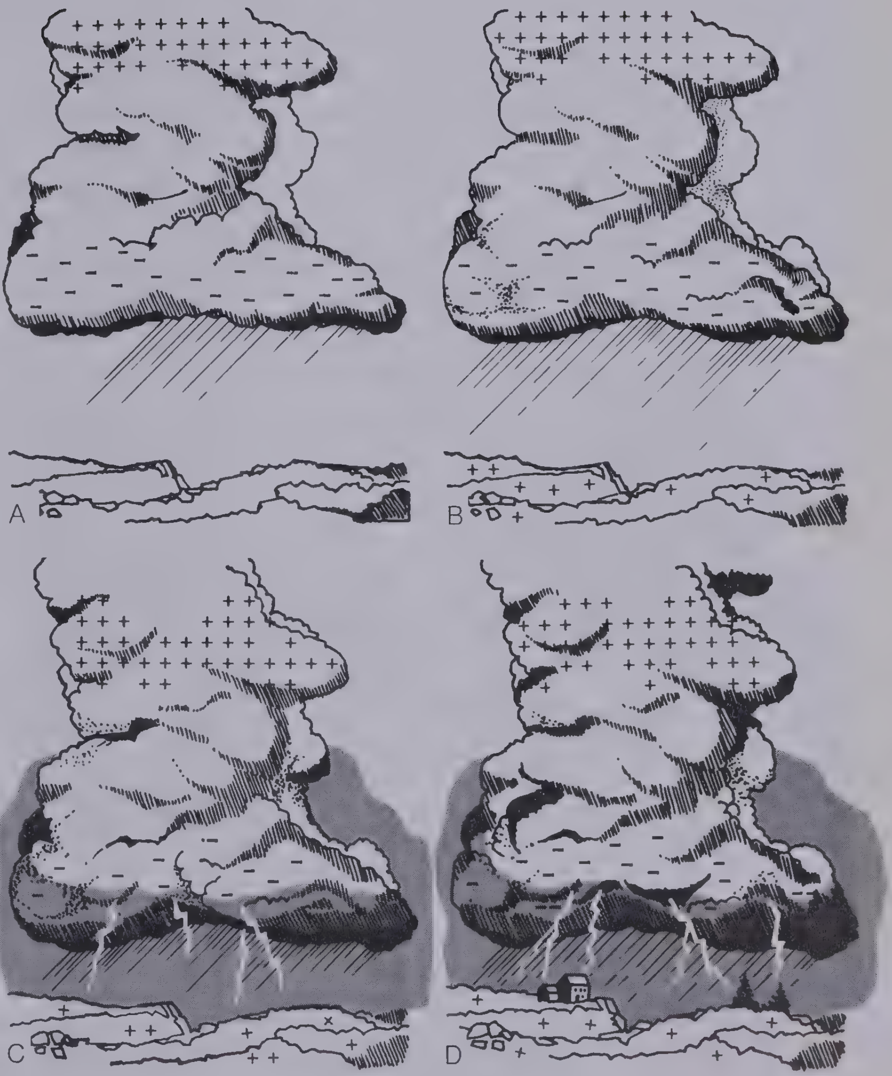


Figure 6-17 *The causes of lightning.*
(A) When a thundercloud is growing, tiny drops of water move up and down many times in the cloud. This charges them. Positive charges collect at the top of the cloud. Negative charges collect at the bottom.
(B) The negative part of the cloud repels electrons in the ground. This makes the part of the ground below the cloud positive.
(C) After a while, if the cloud is low enough and its bottom is negative enough, electrons start moving down out of the cloud toward the earth. A sudden flash of lightning jumps. The lightning usually goes back and forth several times between the earth and the cloud before it stops. The whole time is only about one second.
(D) Lightning is most likely to hit the tallest thing on the ground.

7. Never swim during a storm. Lightning often strikes water. It can travel through the water.

8. Do not carry metal rods (fishing poles or golf clubs) outdoors in a storm.

9. If you are in a car, stay there. The metal of the car conducts the charges to the ground, not to you. This is a very safe place to be.

6-12 Benjamin Franklin flew a kite

Franklin's most famous experiment was with lightning. People had noticed that lightning has the same color as sparks from charged objects and both make a crackling noise. Therefore, they thought that lightning was electric. To test the hypothesis, Franklin flew a kite during a thunderstorm. Sure enough, the ''electric fluid,'' as he called it, came down the string. It made sparks and charged a jar he used in his experiments.

Have you ever wondered why Franklin was not killed by the lightning? The string on his kite would not conduct electricity unless it was wet. He hung a metal key on the end of the string. Then he tied a long silk ribbon to the string. He stood under a shed holding the ribbon. When the rain came, the string got wet. Down came the ''electric fluid.'' It sparked off the end of the key to the ground. But Franklin's ribbon was dry, under the shed. No electricity came his way. He was lucky. If his ribbon had gotten damp he might have been killed.

Did You Get the Point?

Electric fields surround charged objects.

In conductors, electrons move easily when a field is present. In insulators, they do not.

It takes work to separate charges that attract each other. When this happens they gain potential energy.

When they come together again, they change the potential energy into light, heat, and sound energy.

What Have You Learned?

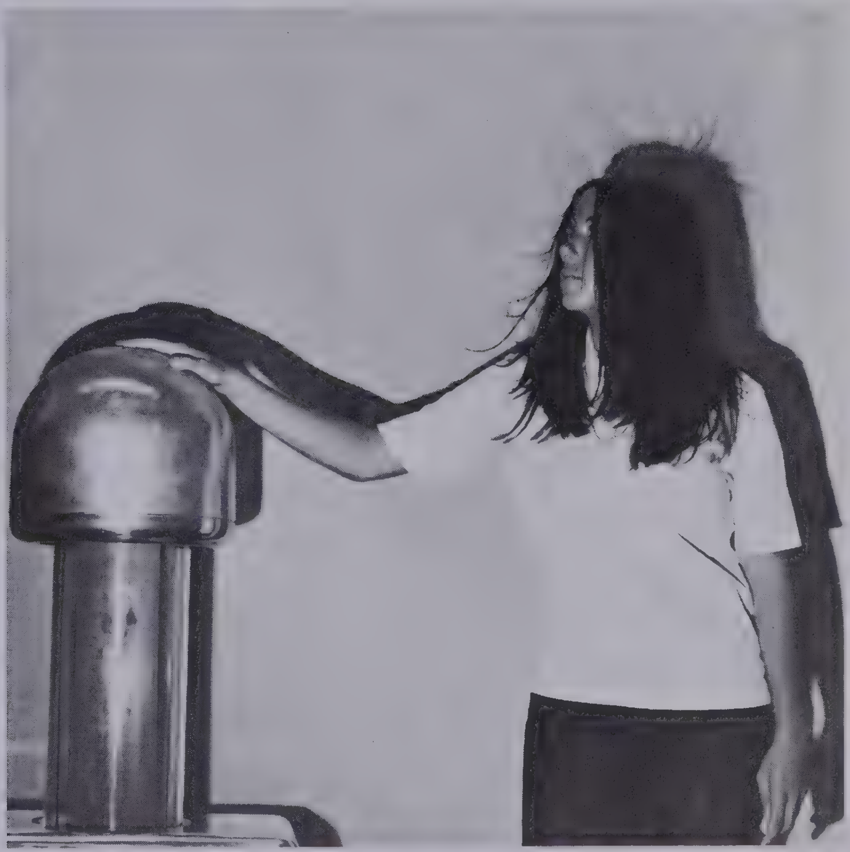
1. Cut a strip of newspaper about an inch wide and four inches long. Hold it against a painted or papered wall. Rub it with a piece of wool. Take the wool away and stop holding the paper. What happens? What happens when you lift up one end of the paper with your fingernail and let go? Explain. Put the paper on the outside of a metal pan and repeat what you did before. Why does it act differently?

2. Sometimes when you comb your hair, it almost stands on end. What makes the girl's hair stand on end in Figure 6-18?

3. Comb your hair quickly several times. Hold the comb near, but not touching, a small stream of water from a faucet. What happens? Why?

4. The Empire State Building is made of steel beams with stone and cement on the outside. How does this help keep people safe when lightning strikes the building?

Figure 6-18 *Are the hairs attracting each other or repelling each other?*



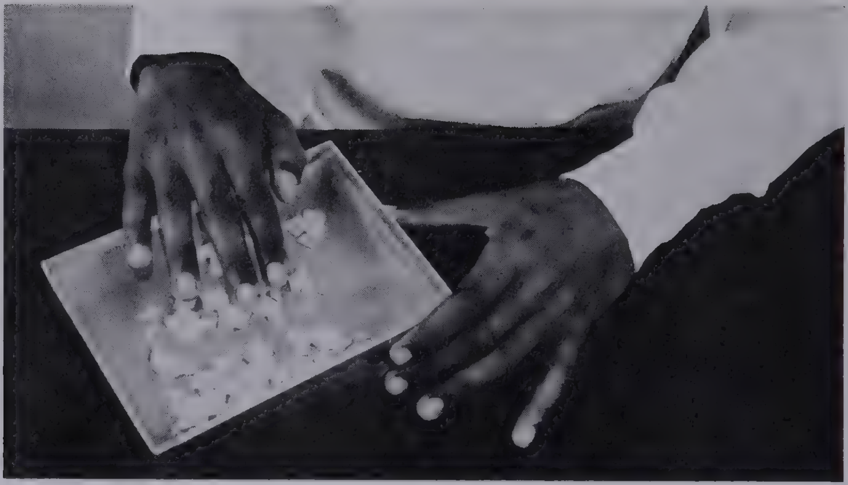


Figure 6-19 *When you make the toy, you can cut some of the paper pieces into snowflakes or other designs.*

SKULLDUGGERY

Make a toy like the one in Figure 6-19. Start with a small cardboard box with a clear plastic lid. Notepaper and greeting cards are often sold in boxes like this. Cut or tear a lot of tiny bits of paper. Put them in the box. Put the lid on. Rub the lid with your hand. Rub rapidly, but lightly. Watch the paper dance. Why does this happen?

FOR FURTHER READING

Basford, Leslie, and Joan Pick. *Lightning in Harness: Foundations of Electricity.* Boston: Ginn and Company, 1966. Covers the bases of electrical theory and technological developments.

Bendick, Jeanne. *Lightning.* Eau Claire, Wis.: E. M. Hale and Company, Pubs., 1961. Simple description of lightning, its action and effects.

Sootin, Harry. *Experiments with Static Electricity.* New York: W. W. Norton and Company, Inc., 1969. Using simple materials, describes more complex instruments.

Viemeister, Peter E. *Lightning Book.* Cambridge, Mass.: The M.I.T. Press, 1972. Experiments made in the field of lightning and weather.

WHAT'S NEXT?

Charging things and making sparks is fun. While doing these things you have learned some theories about electricity. You have also learned how to keep safe from lightning.

However, you know that electricity is important in your life in other ways. You use it for lights, to toast bread, for radio and TV, to keep a clock going. This kind of electricity runs through wires. In the next chapter you will learn about electric current in wires.

Chapter 7

Electric Circuits

Jim was reading. Suddenly the light went out. He reached for the switch on the lamp, but nothing happened when he turned it. ''I'll have to get another bulb,'' he said.

His mother came in. ''The lights went out. I guess the fuse blew. See if you can find the superintendent.''

Jim felt his way to the apartment door and opened it. There was no light in the hall. The neighbors were coming out of their doors, too. ''What happened? Why are the lights out?''

Another neighbor joined them. ''I looked out the window. No lights anywhere. The whole street is dark.''

Jim walked back into his apartment. He found his transistor radio and turned it on. An announcer was speaking. ''All of New York City is without power,'' he said. ''We are running the radio on emergency generators. We have been unable to find what caused the blackout. We will keep you informed as soon as we know more.''

That was the start of the great blackout of 1965. It started near Niagara Falls and kept spreading. Before it was over, most of the northeastern part of the United States and the eastern part of Canada were dark. For some people it was fun. They lit candles and stood outside their apartment doors and talked to the neighbors. Children helped older people walk upstairs, for no elevators were running. Everyone was friendly.

For other people it was terrifying. They were underground in the subway when power went off. They had to walk long distances in dark tunnels to find their way out. Some were stuck between floors in elevators that suddenly stopped.

You can turn one light off with a switch. What makes so many lights go off at once? And in this great blackout why did some go off at first, and then more, and more? You will find some of the answers in this chapter.

Simple Electric Circuits

7-1 Can you light the lamp?

Materials
dry cell, lamp and socket, switch, wire, screwdriver

★ Try putting the things shown in Figure 7-1 together to light the lamp. Study Figure 7-2 to see how to use your wire.

After you have made your lamp go on, see what other groups have done. Does everyone have exactly the same arrangement? In what way are all of the circuits alike? How can the lamp be turned on and off?

What you have made is called an **electric circuit** (SUR-kit). In order for the lamp to light, there must be a complete path. If you start in one place and follow the path, you come back to the beginning. If the switch is open, the path is broken. The light goes out. Open the switch while you read the next paragraphs.

A **circuit diagram** is a simple picture of a circuit. Figure 7-3 shows a circuit diagram and a list of symbols used in diagrams. Study the diagram and symbols. Then use words to describe the circuit.

Figure 7-1 *How can you put these materials together to make the lamp light?*

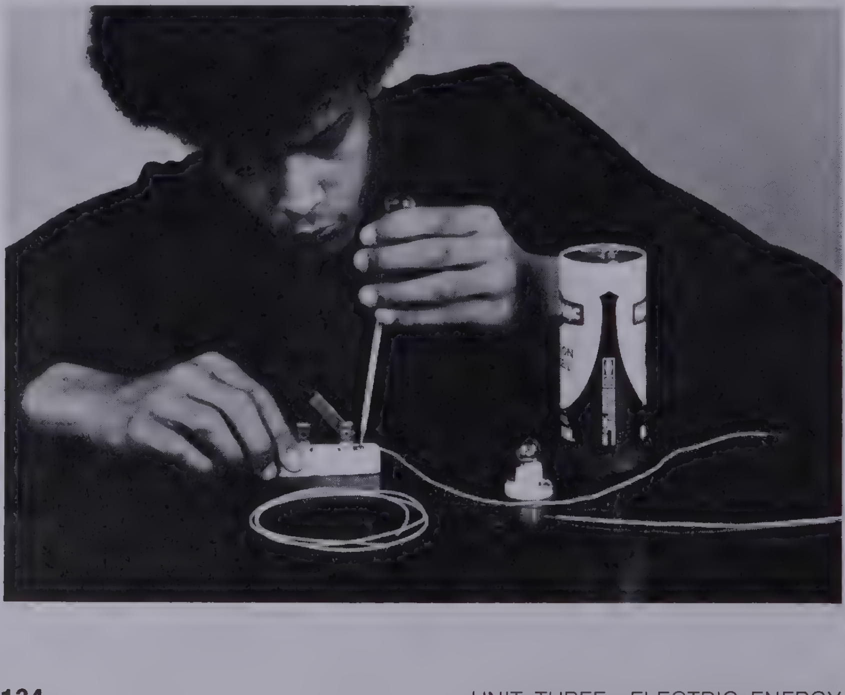
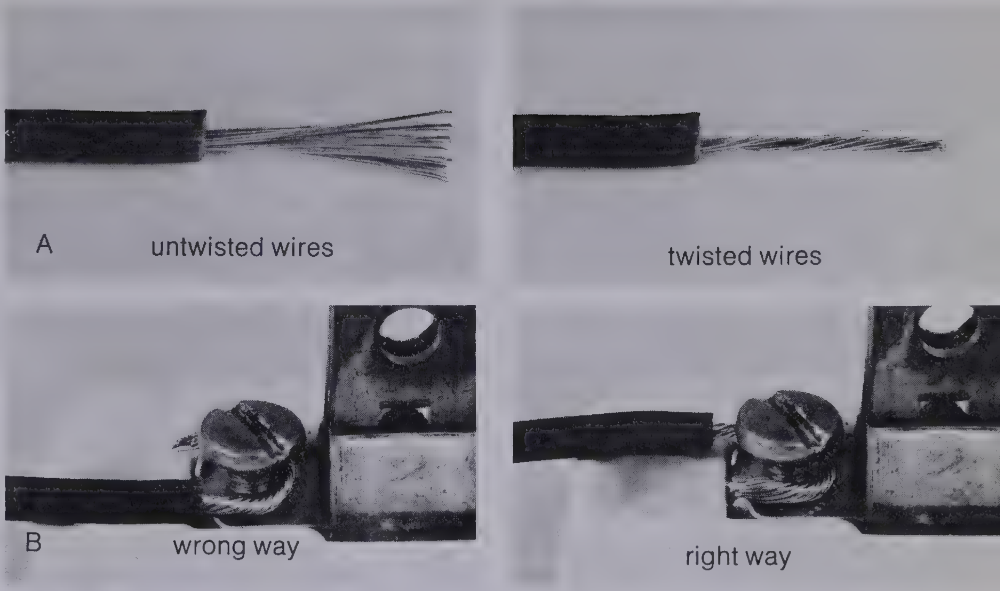


Figure 7-2 (*A*) *Wire with the insulation removed and wire with the strands twisted, ready to use.* (*B*) *Why does it matter which way you bend the wire?*



Notice that the circuit diagram has nice straight lines for the wires. If they turn, they bend at right angles. Real circuits usually do not look like this. In a real circuit, wires may curve around all over the place. Sometimes wires covered with insulators lie on top of each other. If you show the wires the way they really are, it is confusing. A diagram like Figure 7-3A is easier to understand.

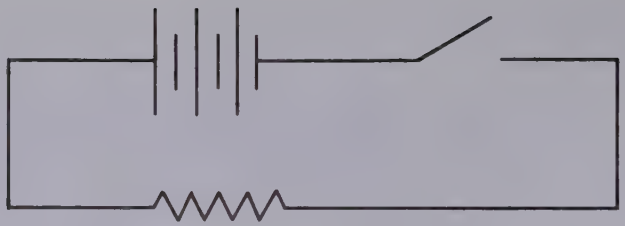
Use symbols to make a clear drawing of your circuit. Put it in your notebook. ★

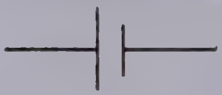
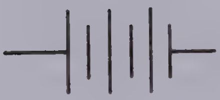
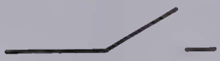
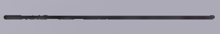
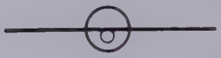
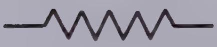
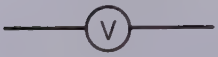
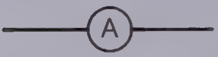
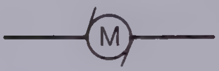
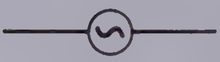
7-2 Why does the circuit work?

The lamp lights when there is current in the circuit. **Current in a wire** is a stream of moving electrons. You may think that the wire looks pretty solid. How is there room for electrons to move? They can move because there is really a lot of empty space inside the wire. It does not look that way because the spaces are so small. But electrons are even smaller.

Electrons are in the wire all the time. But they do not move unless something gives them energy. The dry cell gives energy to electrons. It can do this because it has special chemicals that store energy. When the electrons have used up much of the stored energy, the light will not go on. Then the dry cell is ''dead.''

Figure 7-3



symbol	meaning
	One cell. The long line is the positive (+) side of the cell. You can draw it with the long line on the right and the short one on the left too.
	Three cells connected together. The positive (+) side of each cell is connected to the negative (−) side of the next cell. When two or more cells are connected together, they are called a **battery.**
	Switch, always shown open in diagrams.
	Connecting wire.
	Lamp.
	Resistor. This is a wire that gets hot when electrons travel in it. There is no special number of zigzags.
	Voltmeter.
	Ammeter.
	Electric motor.
	Alternating current electric energy source. This is what you plug into when you use electricity in your house.

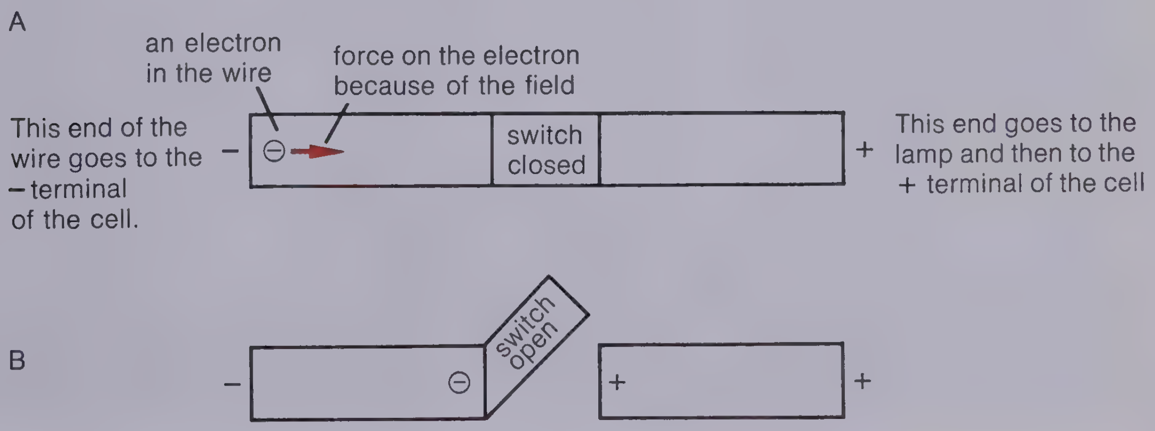
The places where wires can be connected to the cell are called the **terminals.** Find the negative (−) terminal of your cell. The label on the cell will help you. When the switch is open, an electron at the negative terminal has potential energy. But it cannot go anywhere. It is like a ball in your hand. The ball has potential energy because it is higher than the sidewalk. But it cannot drop because you are holding it. When you drop the ball, the potential energy changes to kinetic energy. Closing the switch is like dropping the ball. Electrons move out from the dry cell because there is an electric field in the wire (Figure 7-4). Around the circuit they go.

As the electrons move, they lose energy. Most of it is lost in the lamp. It changes to heat and light. The electrons go around the circuit, back to the dry cell. They have given away the energy that they got from the dry cell. The dry cell gives them more. They are ready to start the trip again.

Every useful electric circuit has four things:

1. A complete path for electrons to travel.
2. Something to give energy to electrons. This is called the **source.** It may be a dry cell or battery (2 or more cells).

Figure 7-4 (*A*) *The electric field pushes the electron along the wire.* (*B*) *When the switch is open, the field keeps pushing electrons up to the opening. The electrons pile up and their negative charge repels any other electrons. Beyond the open switch, the field keeps pulling electrons down the wire. Soon there are no more electrons to come. The end of the wire next to the switch has a positive charge.*


A
an electron in the wire
force on the electron because of the field
This end of the wire goes to the − terminal of the cell.
−
⊖
switch closed
+
This end goes to the lamp and then to the + terminal of the cell
B
−
⊖
switch open
+
+

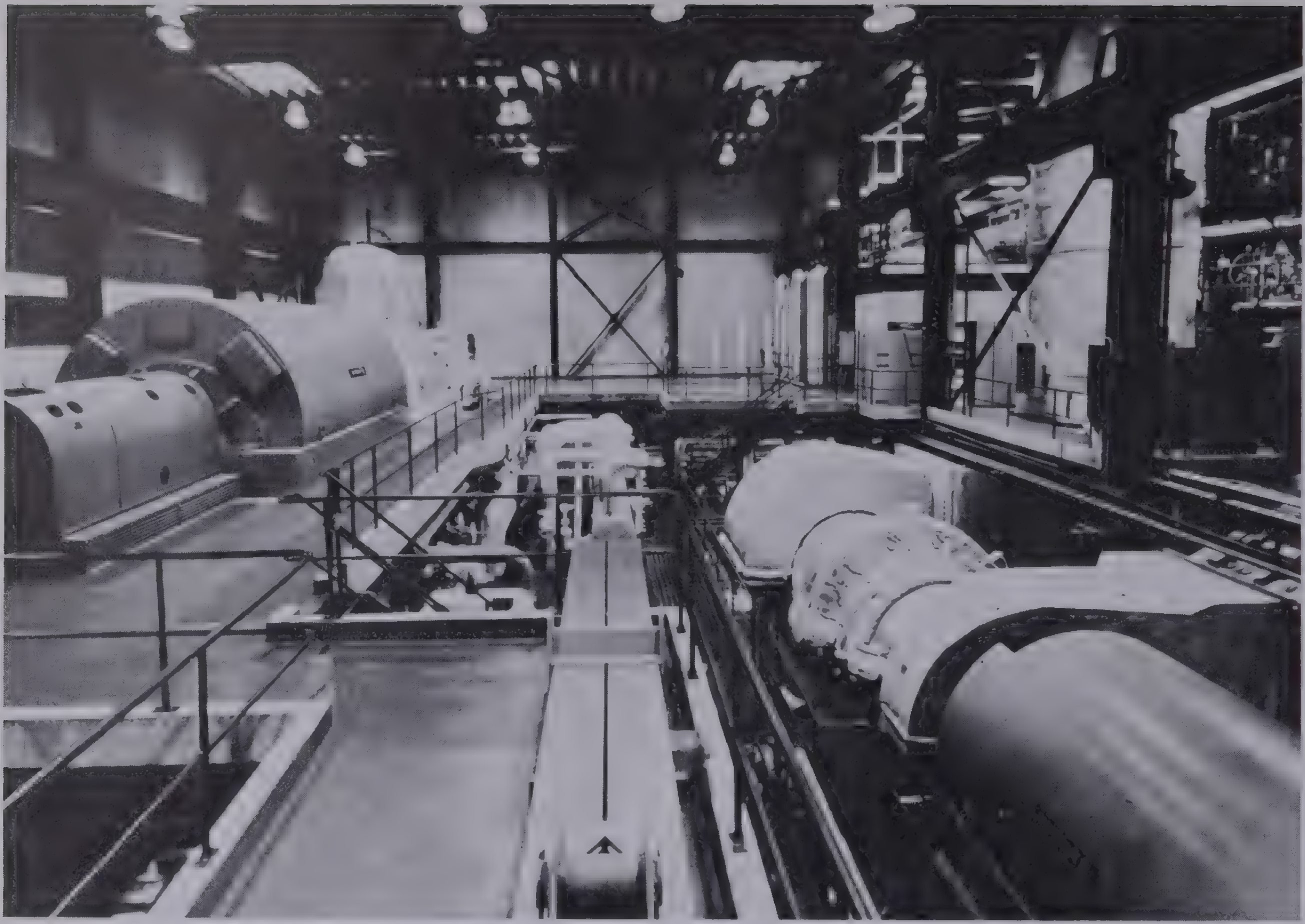


Figure 7-5 *Burning coal in this power plant heats water into steam. Steam runs these generators to make electricity.*

The source for the electric energy in most homes is a generator (JEN-a-ray-tor). A **generator** is a machine that gives energy to electrons. Somewhere, miles away from your home, is a big building with several of these machines (Figure 7-5). Wires connect your house to one of these generators.

3. Something to use the energy. This is called the **load.** In your circuit, the load is the lamp. In other circuits it might be a radio or an iron. The load is whatever is plugged into the circuit.

4. A switch so the current can be turned on and off. A circuit will work without one. But it would be harder to turn it off.

7-3 Conductors and insulators

Electrons travel easily in conductors. They do not travel easily in insulators. You can use your circuit to find good insulators and good conductors.

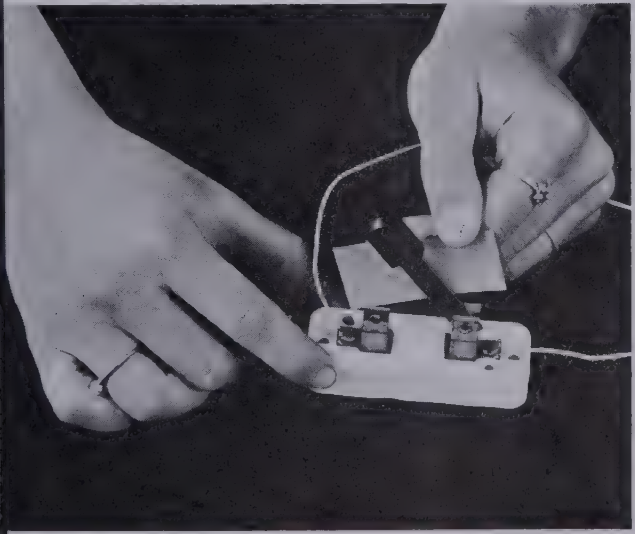
Materials
dry cell, lamp and socket, switch, wire, screwdriver, things to test

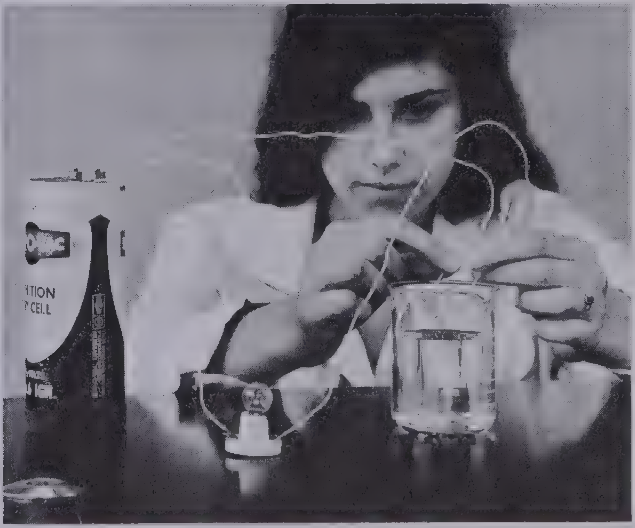
★ Open the switch of your circuit. Make a collection of things to put in the open place. They should be large enough to touch both sides of the switch (Figure 7-6). Try pieces of cardboard, glass, and metal. Bring other materials from home. If the thing is a good conductor, the lamp will light. If it is an insulator, the lamp will not light. If it is a poor conductor, the lamp will light dimly. Make three lists in your notebook: good conductors, poor conductors, insulators.

Next test some liquids. Take the switch out of the circuit completely. Put the liquid in a glass (Figure 7-7). Dip the two wires into the liquid in the glass. Be sure the wires do not touch each other. Try tap water, distilled water, water with dissolved salt, and water with dissolved sugar. Try other liquids if possible. You can also use the glass to test things like sand, dry soil, and wet soil. ★

Figure 7-6 (*left*) *Is cardboard a conductor or insulator?*

Figure 7-7 (*right*) *Is this liquid a conductor or insulator?*





7-4 Measuring potential difference

Your cell is marked 1.5 volts. The **volt** (abbreviation V) is a unit of potential difference. When the cell is new, the potential difference may be a bit higher than 1.5 volts. When it is old, it may be a bit lower. Potential difference is sometimes called **voltage.**

Materials
2 dry cells, 2 lamps and sockets, wire, switch, screwdriver, voltmeter

★ A **voltmeter** measures potential difference. Figure 7-8A shows you how to connect the voltmeter to a cell. Connect the post on the voltmeter that is marked + to the + terminal of the cell. Watch the voltmeter needle while you tap the other wire from the voltmeter on the − terminal of the cell. If the needle goes the wrong way, take the wire away *immediately.* Otherwise you may damage the meter. If the needle goes the right way, fasten the wire.

Figure 7-8B shows the diagram for this circuit. Write down the potential difference of your cell.

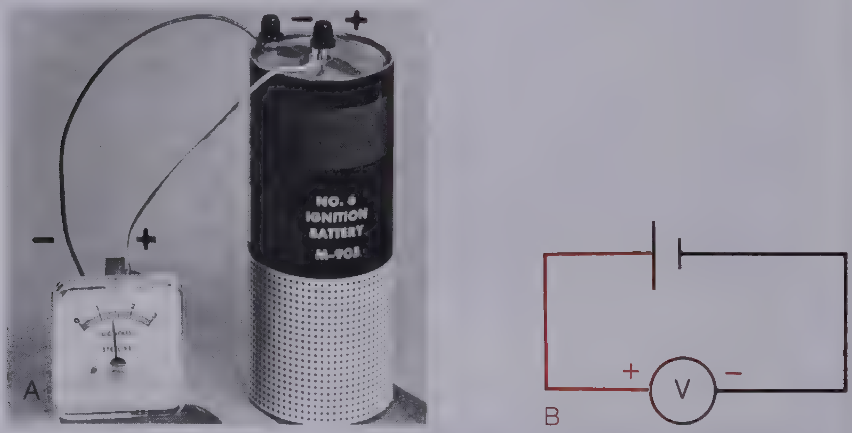


Figure 7-8 (*A*) *Before you fasten the second wire, check to make sure the voltmeter needle goes the right way.* (*B*) *Does this diagram tell you more or less about the circuit than the photo?*

Set up the circuit shown in Figure 7-9A, but without the voltmeter. Close the switch. Then clip the voltmeter into the circuit, watching out for positive and negative sides. If the needle goes the wrong way, change the wires from the voltmeter immediately. Copy the circuit diagram in your notebook. Write down the measured voltage of the battery next to the battery symbol on the diagram.

Next clip the voltmeter into the position shown in Figure 7-9B. Watch the + and − sides of the meter, and watch

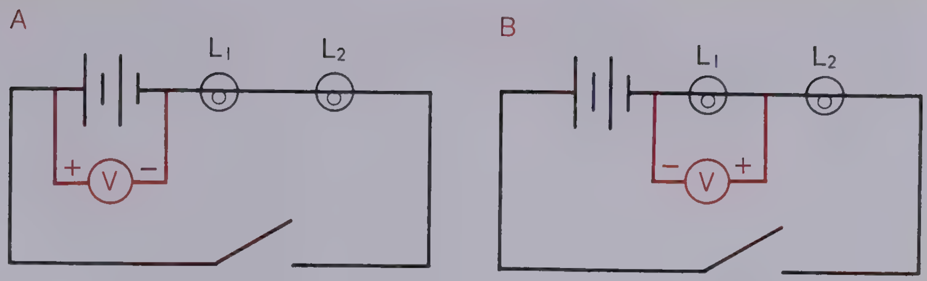


Figure 7-9 *Circuits for Section 7-4. (A) Notice that the positive side of the voltmeter is connected to the positive side of the battery. (B) Why is this the right way to connect the voltmeter? How would you connect the voltmeter to measure the potential difference across L_2?*

the needle when you clip it in. Record the voltage across lamp 1. Move the voltmeter to measure the voltage across lamp 2. Record this in your notebook.

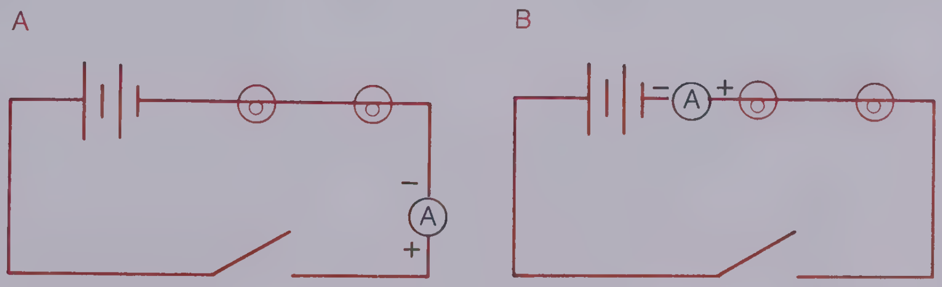
Compare the three voltages you have measured. Discuss the results in class. Write a summary in your notebook. ★

7-5 Measuring current

A current in a wire is a stream of electrons. The stream is measured in amperes (AM-peers, abbreviation A). When the current is one **ampere,** 6,250,000,000,000,000,000 electrons go by in each second. In words, that is six quintillion 250 quadrillion. Do not try to remember this number. The current in a 100-watt light bulb is about one ampere.

Use an **ammeter** to measure current. It looks much like a voltmeter. However, the current to be measured must actually go through it, so it is placed as shown in Figure 7-10.

Figure 7-10 *Circuits for Section 7-5. Will the ammeter measure the same current in each position?*



Materials

2 dry cells, 2 lamps and sockets, wire, switch, screwdriver, ammeter.

★ Wire the circuit of Figure 7-10A. Notice that the + wire from the ammeter goes in the direction of the + side of the battery. The ammeter is easily damaged if you connect it incorrectly. **Do not close the switch until your teacher tells you to.** Then watch the ammeter needle when you close the switch. If it goes the wrong way, open the switch immediately and change the meter.

Measure the current in at least three different places in the circuit. Figure 7-10B shows one way to do it. Discuss your results with the class. Record your observations and interpretations in your notebook. ★

Did You Get the Point?

Every electric circuit needs a complete path for current, an energy source, and a load to change the energy to other forms.

The circuit usually has a switch to open and close the circuit.

In your circuit, the potential difference across the source equals the sum of the potential differences across the loads. This is an example of conservation of energy.

In your circuit the current is the same everywhere.

What Have You Learned?

1. Diagram a circuit with a 3-cell battery, a motor, and a switch.

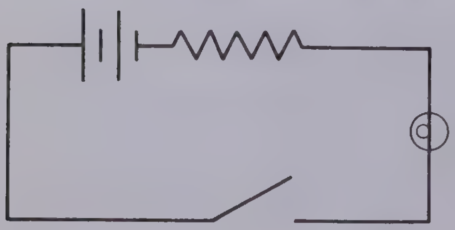
2. Copy Figure 7-11. Show how to connect (a) a voltmeter to measure potential difference across the resistor; (b) an ammeter to measure current in the circuit.

3. In Figure 7-11, the current in the battery is 1 A. What is the current in the resistor? in the lamp?

4. In Figure 7-11, the voltage across the battery is 3 V. The voltage across the resistor is 1 V. What is the voltage across the lamp?

5. Is air a conductor or an insulator? How do you know?

Figure 7-11 *Circuit diagram for What Have You Learned?*



More Complicated Electric Circuits

7-6 Two kinds of circuits

In the circuit of Figure 7-10, both lights went out when you opened the switch. That is not what happens in your house. Each light has its own switch. When you turn off one light, the others stay on.

Materials
dry cell, 2 lamps and sockets, 2 switches, wire, screwdriver

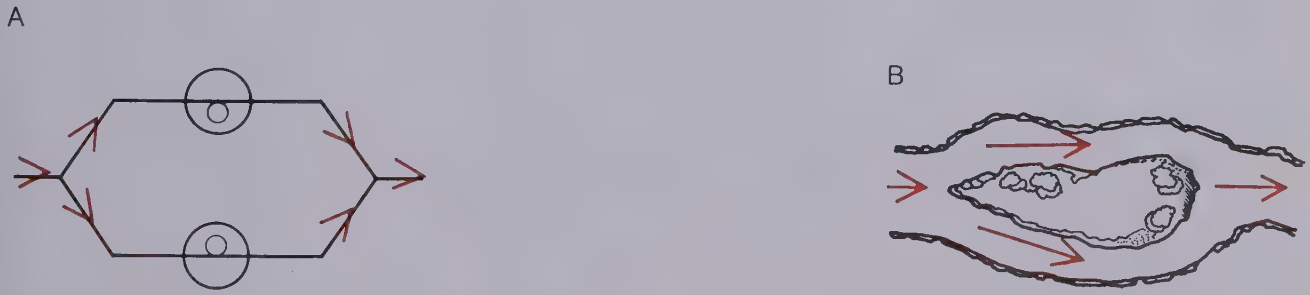
★ Use your materials to make a circuit that lets you turn off one light without turning off the other. When you have a circuit that works, draw the circuit diagram.

The lamps in this circuit are in **parallel.** See Figure 7-12 to understand what this means. Each of the lamps is a separate load. How could you add another lamp and switch to the circuit and be able to turn it on and off without disturbing the others? Try it and diagram the circuit.

The lamps in Figure 7-10 are in **series.** All the electrons that go through one lamp must go through the others. In Figure 7-9 some things are in series and others are in parallel. See if you can tell which is which. In your house, the lights and other appliances are in parallel.

Where could you put another switch in your circuit so that it could turn off all the lamps? Try it. Then diagram the circuit. ★

Figure 7-12 (*A*) *In a parallel circuit the current splits. Part takes one path, part another. Then the current comes together again.* (*B*) *Why is a parallel circuit like a river flowing around an island?*



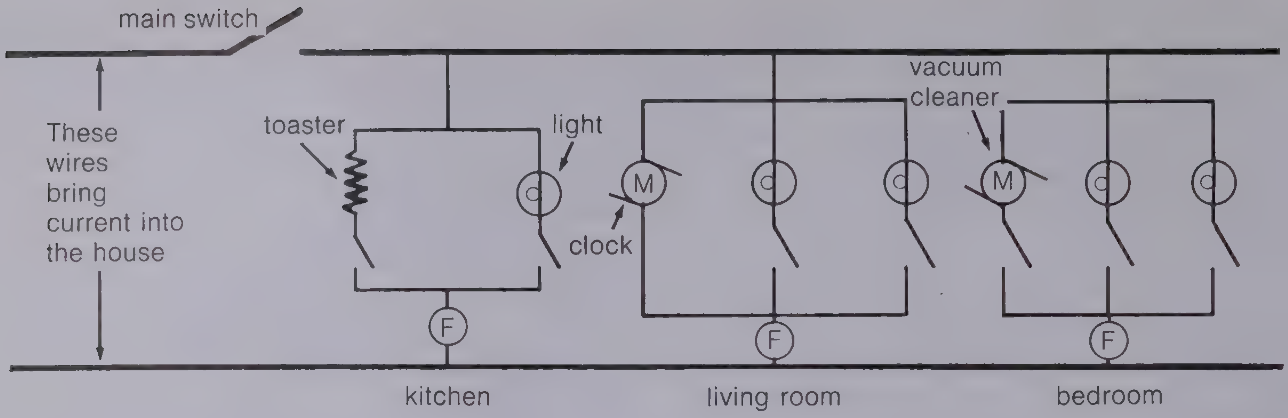
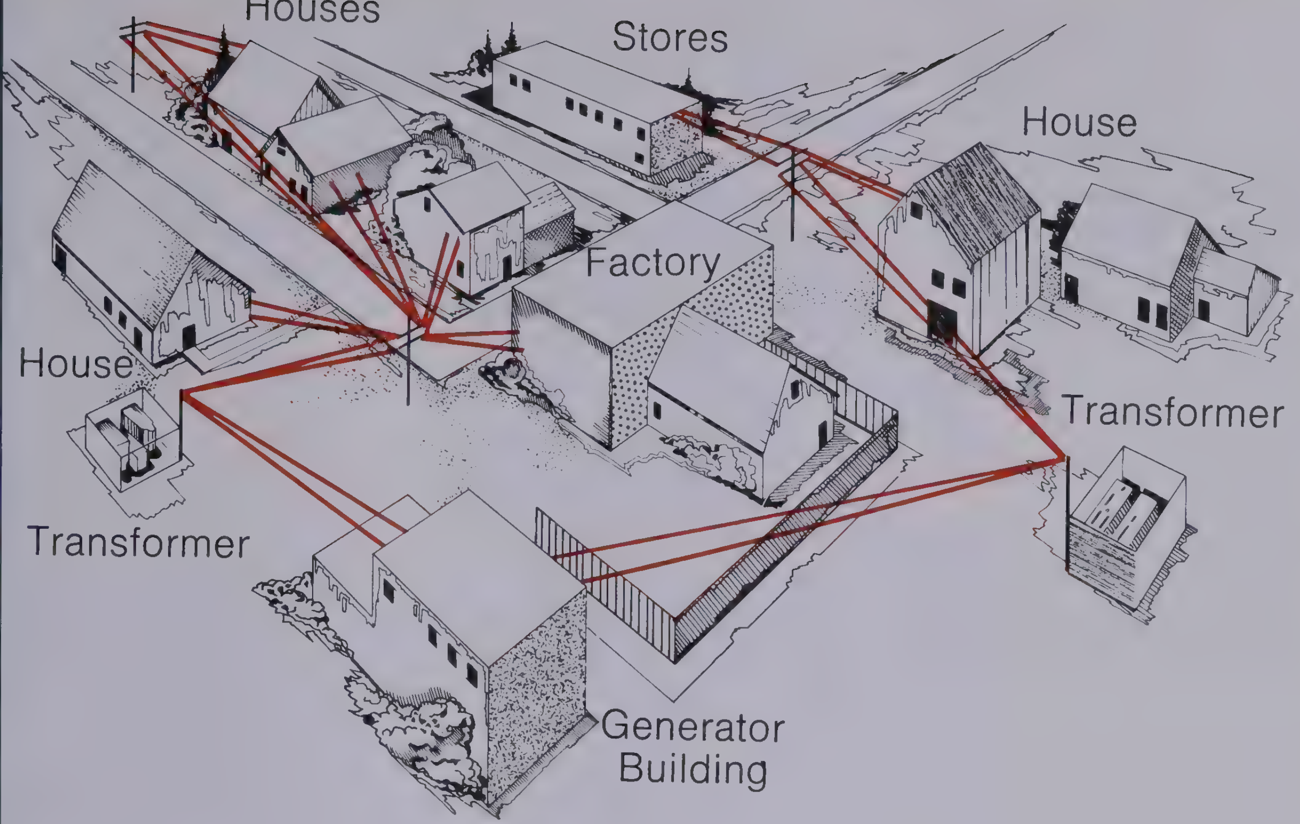


Figure 7-13 *An* F *in a circle means a fuse. Why is it a good idea to have several circuits in a house?*

In your house, the switch that turns everything off is called the **main switch** (Figure 7-13). It is used when electricians must work on the circuits. The house in Figure 7-13 has three circuits, one for each room. The kitchen is in parallel with the living room and bedroom. In the kitchen, the toaster is in parallel with the light. The fuses are switches that shut off their own circuits if the wires get too hot. The clock and vacuum cleaner are drawn with motor symbols because they have motors. Why is there no switch for the clock? Where is the switch in a toaster?

Circuits for many houses and businesses are connected in parallel (Figure 7-14). The generator sends out current at a very high potential difference, thousands of volts. This voltage could easily kill you. Many parallel circuits are connected to the generator. A transformer near the houses lowers the potential difference to 110 or 120 V. Wires connect many houses in parallel to each transformer.

A main switch in the generator can cut off all the circuits. A main switch in a transformer cuts off the houses connected to it. If a generator breaks down, all the circuits connected to it go dead. Sometimes the generator cannot be fixed right away. Then special switches connect the circuits to other generators.



igure 7-14 *Transformers often are placed inside metal contain-
rs high on telephone poles. Can you find one near your
ouse?*

7-7 Fun with switches

Mary came home from school. It was late in the afternoon in winter. She put on the light in the hall and ran upstairs.

"Put out the light," called her mother. "The bill was too high last month."

Instead of running back downstairs, Mary went to a switch at the top of the stairs. She had used one switch to turn on the light. Now she used a different one to turn it off.

You can make a circuit work this way. You need **double throw switches** (Figure 7-15A). Notice that there are two ways to close the switch. This is why it is called double throw.

Materials
dry cell, lamp and socket, 2 double throw switches, wire, screwdriver

★ Set up the circuit shown in Figure 7-15B. Notice that the symbol for the switch has two dots. Each dot stands for one of the screws on the switch. The part that closes the switch is attached to the middle. Set up the circuit carefully. You will be able to turn the light on or off with either switch. ★

7-8 The real thing

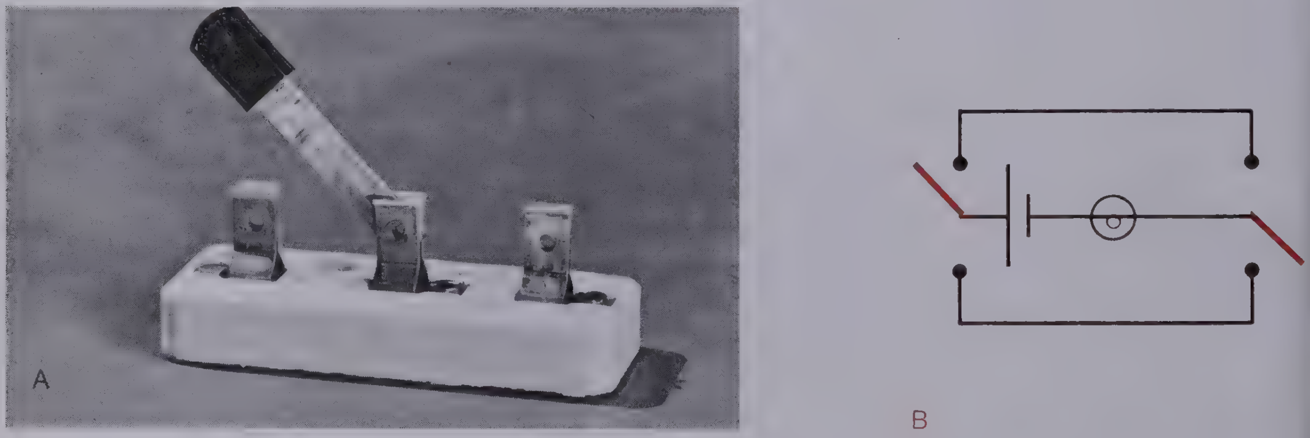
You can fix some things around the house. To learn how, try these exercises:

Materials
wall switch, wire, wire strippers, extension cord plug, screwdriver, fuse

★ 1. Strip insulation from the end of a wire. **Insulation** is the covering that keeps electrons from getting out of the wire. Insulation is made of an insulator, like cloth or rubber. With wire strippers, make a cut through the insulation all around the wire. Be sure not to cut the wire. Push the insulation off. Twist the strands of wire together.

2. Disconnect the wire from an extension cord plug. Notice that the wire curls around the screw in the same

Figure 7-15 *(A) A double-throw switch. A double-throw switch in a house is never open like this. It is always closed one way or the other. (B) How many different ways can you connect this circuit and make the lamp light?*



direction that the screw turns down. Notice the knot in the cord. This keeps people from pulling wires out of the plug easily. Undo the knot. Figure 7-16 shows how to tie the knot. Tie it and put the end on the cord again.

Be sure you have tucked all strands of wire under the screws. Sometimes, bits of wire from one side of the plug touch bits from the other side. Then electrons go from one side to the other without going through the load. This is called a **short circuit.** It makes the plug and wires very hot. A fire could start.

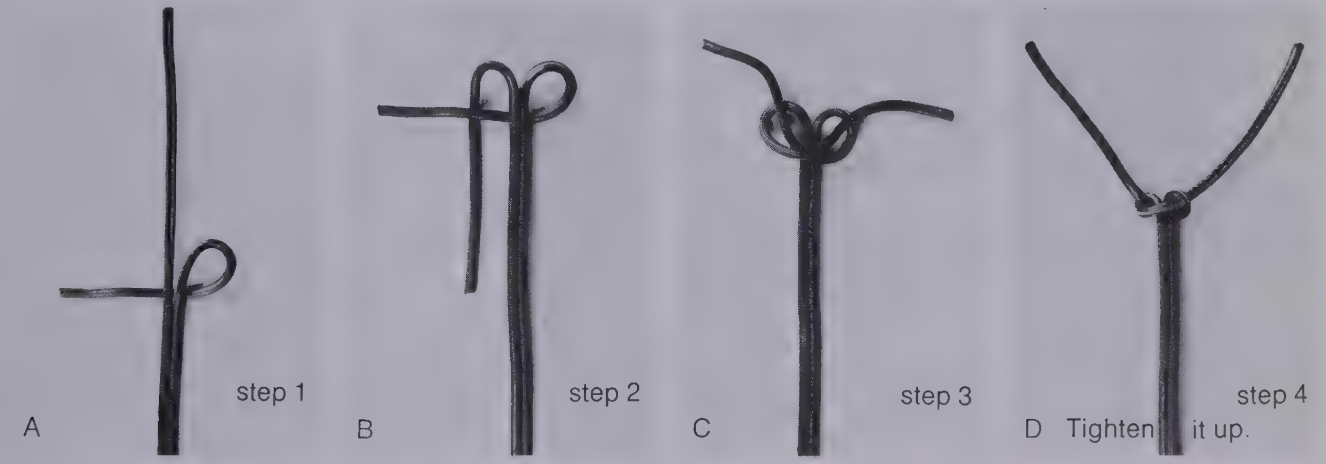
Many cords have plugs molded on them. You cannot take them apart. But sometimes a cord wears out near the plug. Then cut off the molded plug and put on a new one like the one you used in class.

3. The switches in your house do not look like the ones you have been using. But they are really not very different. Examine switches like the ones in your house. Decide which are simple switches and which are double throw. Notice where the wires are connected.

The voltage in your house has been lowered by the transformer outside. However, it is still high enough to be dangerous. Switches like these should be put in by an expert. He knows how to connect them safely. Do not try to work with a switch in your house.

4. Examine a fuse. Notice the metal that goes across inside the glass. This metal melts easily when it gets hot. If you have a short circuit or if you turn too many things

Figure 7-16 *How to tie wire so that it is hard to pull it out of the plug. This knot is called an underwriter's knot.*


A step 1

B step 2

C step 3

D Tighten it up. step 4

on at once, there is a big current. Then the wires get hot and could start a fire in the walls of the house. If there is a fuse in the circuit, the metal melts. It acts like a switch. The current stops before there is enough heat to start a fire.

Automobiles have fuses in the headlight circuit. They protect the lights from getting too much current and burning out. Sometimes ammeters and voltmeters have fuses. This keeps them from getting enough current to damage them.

NEVER put a piece of metal in place of a burned-out fuse. Fuses are to keep a house safe. They also protect expensive equipment. If a fuse burns out, find out what made the current too big. If too many things were plugged in, or if there was a short circuit, unplug what was making the trouble. Then put in a new fuse. The largest current that is safe for the wire is marked on the fuse. If you take a melted fuse out of a fuse box, put one back in that is marked for the same number of amperes.

Many house circuits have magnetic **circuit breakers** instead of fuses. These are switches. They open by themselves when the current is too big. If this happens, find out what made the current too big. Fix it. Then close the switch in the circuit breaker.

5. If there is time and your teacher approves, bring something from home that needs a new cord or switch or socket. Your teacher will tell you what to buy to fix it and will help you. Do not bring a radio or motor. They are usually too hard to fix. ★

7-9 Safety rules

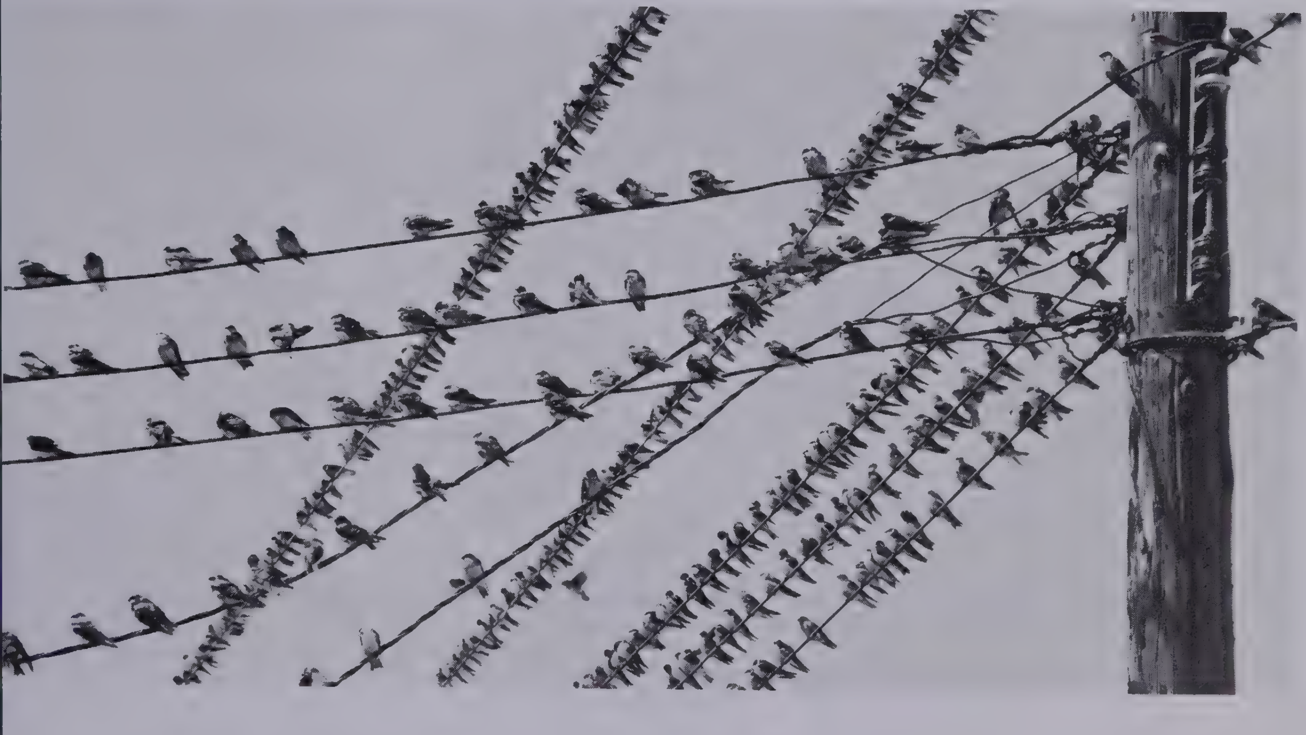
In school you worked with 1.5-V and 3.5-V potential differences. These are safe. In your house most voltages are about 110 and some are 220. This is enough to kill you.

It is not the voltage that kills. It is the size of the current through your body. Current goes through you if you are part of a circuit. The birds in Figure 7-17 are sitting on electric wires that have no insulation. The potential difference between two of these wires is thousands of volts. But the birds touch only one wire. They are not part of a circuit, so they are safe. If a long-legged bird put one foot on one wire and the other on a different wire, he would be killed. He would complete the circuit.

You can hold one wire in a 110-V circuit and be safe if you are not part of the circuit. There are many ways to complete a circuit. If you happen to touch an electric wire with one hand, and a faucet with the other, you become part of a circuit. Current goes from the wire into your hand, through your body, out your other hand, down the pipes to the ground.

Your body is a better conductor when your hands are wet than when they are dry. When you are a better conductor, more current will go through you. Suppose you touch a switch with one wet hand and a faucet with the other. If the switch has good insulation, nothing happens. But sometimes the insulation is not good. Then you complete a circuit. You feel a shock. Many people have been killed this way. When your hands are dry, you are safer. Then if any current goes through you, it will be small.

Figure 7-17 *Do the birds make a short circuit? Why or why not?*



If you get a shock from an appliance, stop using it until it is fixed. Never use an appliance that has a cord that looks worn. The insulation may not be good enough to protect you from a shock.

Did You Get the Point?

One switch in a series circuit turns everything in the circuit on and off.

When loads are in parallel, each load can be turned on and off separately.

Main switches control many circuits.

Fuses and circuit breakers open a circuit when it gets too hot. This protects houses and equipment from harm.

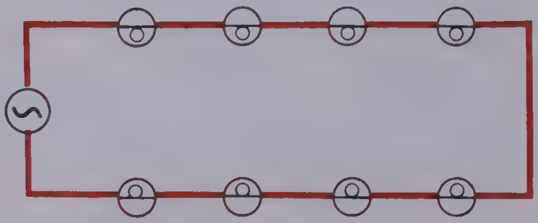
Never touch anything electric with wet hands.

What Have You Learned?

1. Without looking in your notebook, draw these circuits. Then look in your notebook to see if you are correct. (a) A circuit with two lamps. Each one can be turned off without bothering the other. (b) A circuit just like the one in (a), but with three switches. One turns one lamp off. Another turns the other one off. The third turns them both off.

2. Christmas tree lights are sometimes wired as in Figure 7-18. If one bulb is no good, what happens?

Figure 7-18 *Wiring diagram for Christmas tree lights for What Have You Learned?*



3. The girl with her hair on end in Figure 6-18 is not hurt, although she is highly charged. Why?

4. When you worked with charges in Chapter 6, you got rid of them by grounding. How does this work?

SKULLDUGGERY

1. Read this story and draw a map of the adventures of the electrons.

Elec and Tron came out of a battery. They were full of energy. They came to a switch. It was closed, so they hurried through it. Next was an electric lamp. They ran through it, bumping into particles in the wire. The particles jiggled faster.

''We really made that wire hot,'' said Elec.

''Yes,'' said Tron, ''but it made me tired.''

They came to a fork in the path. Elec went one way. Soon he was helping to turn a motor. Tron took the other path and heated the wire in a light. Their paths met again. Suddenly all the electrons in the wire stopped. Someone had opened the switch. When it closed, they started again. By now they were tired, so they were glad when they arrived at the battery.

''I'm feeling a lot better,'' said Elec as he went through the first cell.

''Me, too,'' said Tron as they went through the second.

''Ready for more fun,'' said both, as they came out of the third cell.

2. Your teacher will give you a copy of the puzzle (Figure 7-19). Do not write in the book. Read each definition. Write the word in the puzzle. The letters in the vertical box will spell out something that every electric circuit should have.

Definitions

1. When you connected wires, lamps, cells, and a switch, you made an electric ____.
2. The part of a circuit that uses the energy.
3. A meter to measure potential difference.
4. A current is measured in ____.
5. A material that is a very poor conductor.

6. An important part of a circuit that protects wires from getting too hot.
7. A part of a circuit that gives energy to electrons.
8. A flow of electrons in a wire.
9. A voltmeter should always be connected this way in a circuit.
10. A circuit ____ is a simple way to make a picture of a circuit.
11. A thing that turns a circuit on and off.
12. If a person is careless when he attaches a plug to a cord end, he may leave loose wires. If current goes across these wires, there is a ____ circuit.

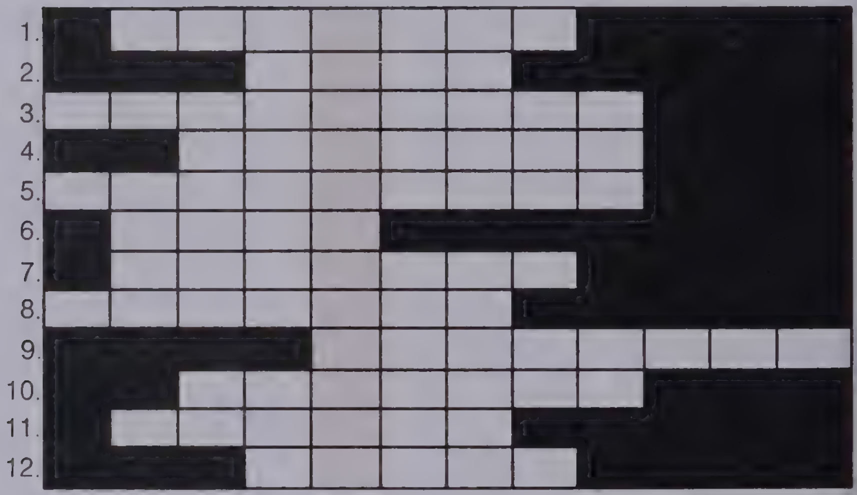


Figure 7-19 *Puzzle for Skullduggery Question 2.*

3. Check your home for electrical dangers. Are there any frayed cords or bare wires? Are the electrical outlets within the reach of a small child? How could these outlets be protected? How many outlets are there for each fuse? If all the appliances were plugged in at the same time, would you blow a fuse?

4. How many things in your home use electricity? How many of them are usually turned on at the same time?

5. Suggest some ways that you could use less electricity in your home.

FOR FURTHER READING

Collins, Frederick. *The Radio Amateur's Handbook: How to Make and Operate Your Own Radio,* rev. ed. New York: Crowell Collier and Macmillan, Inc., 1970. A thorough study of principles and practical plans for construction and operation.

Epstein, Sam, and Beryl Epstein. *First Book of Electricity,* rev. ed. New York: Franklin Watts, Inc., 1966. What electricity is, how it is harnessed, how it travels, and how appliances work.

Mandelbaum, Arnold. *Electricity: The Story of Power.* New York: G. P. Putnam's Sons, 1960. A historical survey of electrical discovery and invention.

Upton, Monroe. *Inside Electronics.* Old Greenwich, Conn.: The Devin-Adair Co., 1964. Describes radio, stereo, and hi-fi.

WHAT'S NEXT

Perhaps you have played with a magnet. Some magnets will pick up a whole pile of paper clips or a bunch of large nails. But there are stronger magnets than that. Some magnets are strong enough to pick up a car. When you pick up paper clips with a magnet, you can easily pull them off again. But suppose you managed to pick up a car with a magnet. How would you get the car off the magnet? It's very easy, really. You will learn about it in the next chapter.

Chapter 8

Magnets and Electricity

About a hundred and fifty years ago, this is what some of the materials used in a school science laboratory looked like. Can you figure out what some of them are? In the picture you can find a battery, some wire, and a compass. They do not look like the ones we use today.

In those days, if you wanted a battery, you had to make it from chemicals and sheets of metal. The battery was sticky and wet and it did not last very long.

One day Hans Christian Oersted, a teacher in Denmark, made a battery. He wanted to show his students how an electric circuit works. After the class he kept on playing with the battery because it would be useless in a few hours. He wanted to get all the use out of it that he could. Some of the students stayed to watch.

Once when he closed the switch of his circuit, something happened that he had not expected. The thing that happened was not an explosion or a spark or anything that might seem exciting. It was something very quiet. If the teacher and his students had not been watching carefully, they might have missed it.

Because of that quiet discovery, people have learned how to make doorbells and loudspeakers and transformers and the big lifting magnets that move junked cars. You will learn about the discovery in this chapter.

Magnets

8-1 What is attracted by a magnet?

Materials
round magnet

★ Probably you have played with magnets before, without bothering to make scientific observations. Get a magnet from your teacher. See how many observations you can make when you and other students put your magnets together.

Discuss your observations with others in the class, and make a list for your notebook. Later you will be able to explain them better. ★

Materials
magnet, materials to test

★ Use your magnet to test materials. Make two lists in your notebook, one for things that are attracted by the magnet (**magnetic materials**) and one for things that are not attracted (**non-magnetic materials**). If possible, write the name of the material each time. For example, write "plastic pen" in your list, not just "pen."

You should be able to find at least ten things to test. Don't forget things like your clothes and hair, as well as all the different things in your pockets and school supplies.

After you have tested ten things, borrow some of the samples your teacher has collected.

What generalization can you make about magnetic materials? Write it in your notebook. ★

8-2 How do magnets behave?

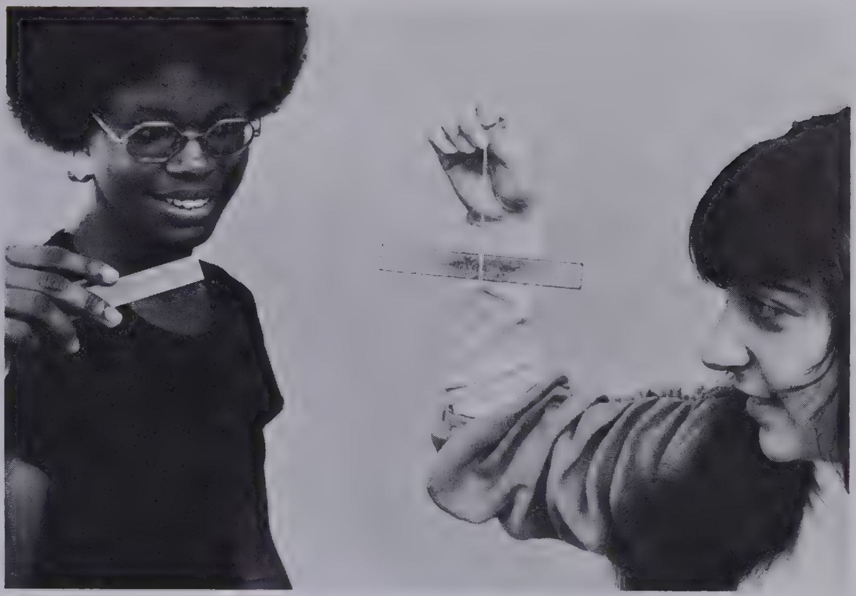
Materials
2 bar magnets, string

★ Notice that the magnets to be used in this activity are marked N and S. The N end is called the north pole of the magnet; the S end is the south pole.

Tie the string around one of the magnets. Hold the string so the magnet hangs as shown in Figure 8-1. Bring the other magnet near the hanging magnet. Write in your notebook what happens when you try to (1) bring two N poles near each other; (2) bring two S poles near each other; (3) bring two opposite poles near each other. ★

When you did the experiment with electric charges, you discovered this rule: Charges that are alike repel; charges that are different attract. The rule for magnets is almost the same: **Poles that are alike repel; poles that are different attract.**

Figure 8-1 *Tie the string so that the magnet hangs level.*



There is one big difference, however, between magnets and charges. Any object can be charged, so the charge rule applies to everything. Not very many things can be made into good magnets, so the magnet rule does not apply to most materials.

The magnets you have been using are all made of iron or steel (which is mostly iron).

Use the magnet rule to explain why your round magnets did what they did. Use it also to decide where the north and south poles were in these magnets.

8-3 How magnetic poles got their names

Materials
bar magnet, string

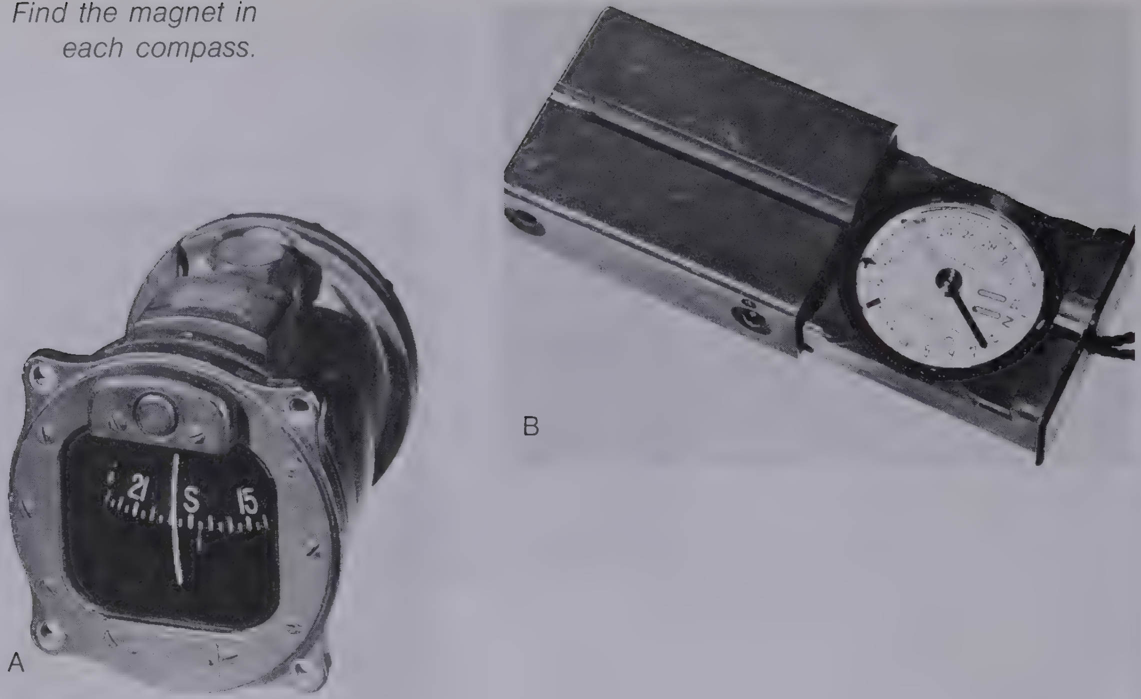
★ Hang up the bar magnet again, as in Figure 8-1. This time, be sure there is no other magnet or anything made of iron near the hanging magnet. After it stops swinging, notice which way it lines up.

Now, with the magnet still hanging, twist it so that it is completely turned around. Let go and notice which way it lines up when it stops swinging.

Do the other magnets in the class line up the same way?

Your teacher will tell you which way is north in your room. Use the directions north, south, east and west to describe the way the magnets are hanging. Write this in your notebook. ★

Figure 8-2 *Find the magnet in each compass.*



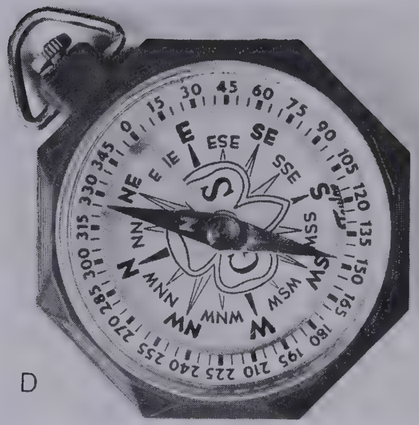
Over most of the world magnets point north and south when they hang so that they can swing. This is how the poles of the magnet got their names. The end that points north is the **north pole** (**N pole**); the end that points south is the **south pole** (**S pole**).

Hundreds of years ago, people were often afraid to sail their ships far out of sight of land because they might get lost. If they sailed west, away from the land, then they could get home by sailing back east. They could tell the directions by the sun in the daytime and by the stars at night. But in cloudy weather they might not know which way to go to find land again.

When people discovered that a swinging magnet would always point north and south, they took a hanging magnet along in their ships. Then they could find their way even when the sky was cloudy.

A **compass** is a magnet that turns inside a case, with the directions marked. Look at Figure 8-2. Which part of each compass is the magnet? If you have a compass yourself, look at it to see how the magnet hangs up. Usually the magnet is pointed at the ends, and the north end is marked in some way, often by a special color.

C



D

Did You Get the Point? Iron is the best magnetic material.

Magnetic poles that are alike repel. Poles that are different attract.

When a magnet hangs so that it can swing, it will point north and south.

What Have You Learned? **1.** In Figure 8-3 are several drawings of magnets. In each case, will the magnets pull closer together, push each other apart, or stay as they are?

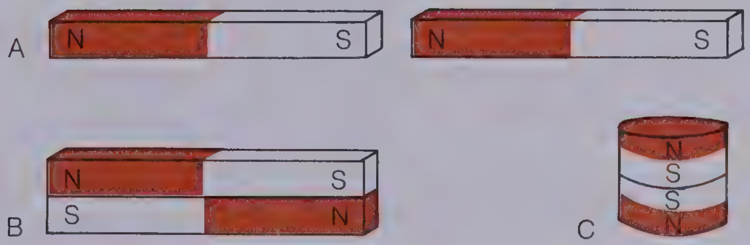


Figure 8-3 *Magnets for What Have You Learned?*

2. Which of these things will a magnet probably pick up? (a) a marble (b) a penny (c) a nail

3. Screwdrivers are often magnetized. Why is this a good idea?

4. Mary dropped her sewing pins on the floor. She was able to pick up most of them but some were in the cracks. She went and got her magnet. But it would not pick up the pins.

"Mom," she said. "My magnet is no good. It won't pick up my pins."

"Try it on the scissors," said her mother.

The magnet stuck to the scissors.

"I don't understand," said Mary. "Why does it stick to the scissors and won't pick up the pins?"

"Try it on your pins in the box," said her mother. "Maybe the pins in the crack are too far away."

So Mary tried, but the magnet would not pick up any pins from the box.

Can you explain things for Mary?

Magnetic Fields

8-4 Every magnet is surrounded by a magnetic field

In Chapter 6 you learned about electric fields. Magnets have fields too. Each kind of field can push or pull things in the field. It exerts a force on objects in the field.

Electric fields exert forces on objects that are charged. **Magnetic fields** exert forces on objects made of magnetic materials. Which things in Figure 8-4 might feel a force in an electric field? Which ones might feel a force in a magnetic field?

Every magnet is surrounded by a magnetic field. The field is strongest near the magnet and gets weaker farther off. The field goes on forever, getting weaker and weaker.

Figure 8-4 *Do electric fields affect these objects? Do magnetic fields affect them?*

Materials
bar magnet, compass

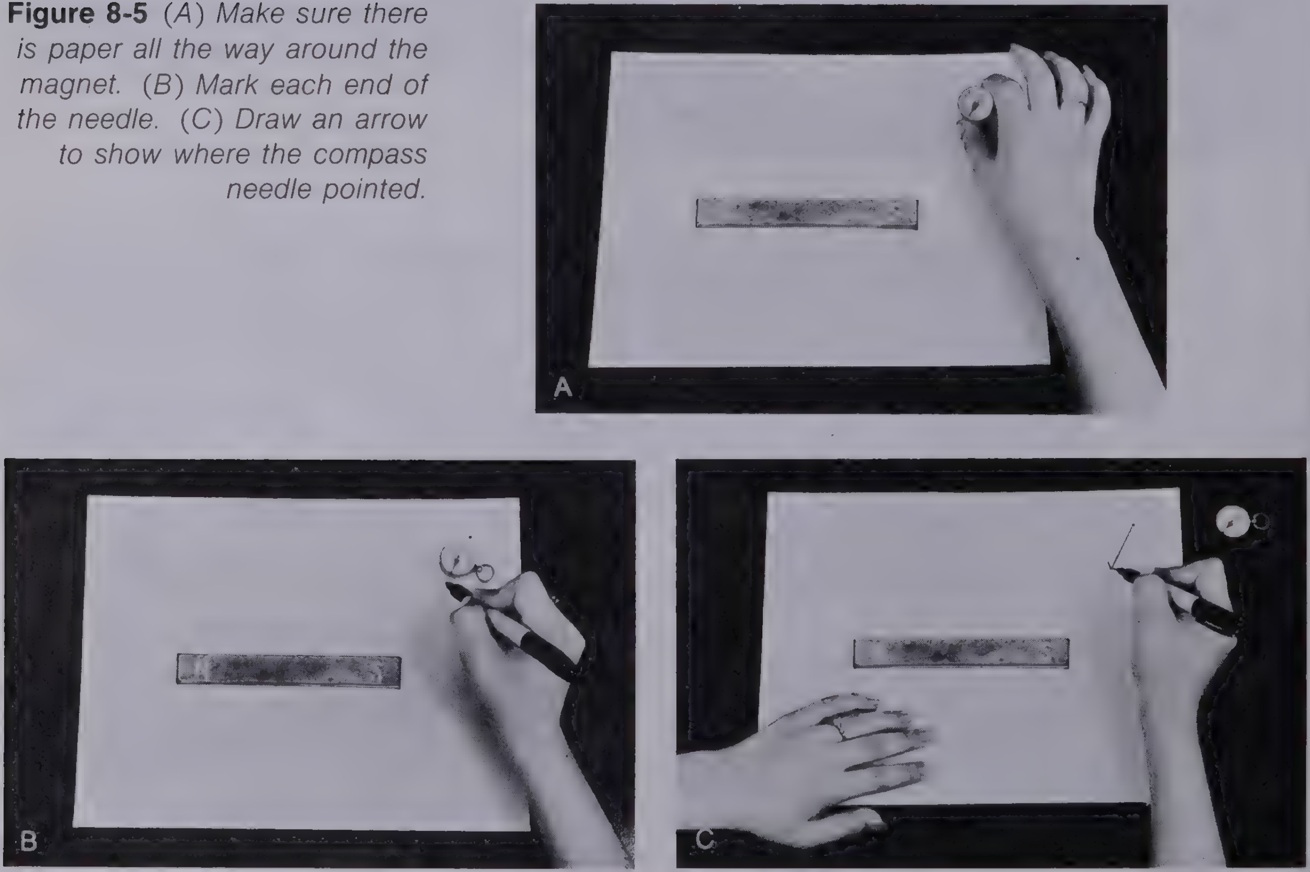
★ The needle in a compass is a tiny magnet. It can be used to explore the magnetic field of a bigger magnet. Put a bar magnet on a sheet of paper on the table (Figure 8-5A). Draw around the edges of the magnet on the paper.

Put the compass anywhere on the paper and notice how the needle points. Make dots on each side of the compass near the ends of the needle (Figure 8-5B). Then pick up the compass and make an arrow between the points on the paper with the head of the arrow on the N side of the needle (Figure 8-5C).

Leave the magnet where it is and move the compass to a new position. Make an arrow to show how the needle points here. Repeat this until you have five or six arrows. You and your partner should each have a map like this, so you will have to repeat with another sheet of paper.

You have been recording the direction of the magnetic field. Notice that it is different in different places. The **direction of the magnetic field** is the direction in which the

Figure 8-5 (*A*) *Make sure there is paper all the way around the magnet.* (*B*) *Mark each end of the needle.* (*C*) *Draw an arrow to show where the compass needle pointed.*



N end of a compass needle points. What can you say about the direction of the field near the N pole of a magnet? What about the direction of the field near the S pole? Write your answers on the map you have just made. If necessary, look at maps made by other people to help you answer the questions.

This magnet makes it seem that a magnetic field is flat, but it is not. Invent a way to show that there is a magnetic field above and below the magnet too. ★

8-5 Magnetic fields have many shapes

Materials
2 bar magnets, box lid, iron filings

★ In this activity you will use iron filings to find the shapes of magnetic fields. This can be messy, because if you get the filings on the magnet, they are not easy to get off. Follow the directions and see if you can keep your magnet clean.

Put a bar magnet on the table. Put the box lid over it, with the edges up. Sprinkle iron filings lightly on the lid, about the way you would salt an egg. Too many filings will spoil the picture. Now hold the box lid at one corner so it cannot slip, and tap it very gently at the side with the other hand. The iron filings will line up to show the shape of the field. If you do this correctly, the filings will look like the ones in Figure 8-6A.

Make a drawing to show the shape of the field. Figure 8-6B shows how one student did this. Notice that arrows are on the lines to show the direction of the field, and that the N and S poles of the magnet are marked.

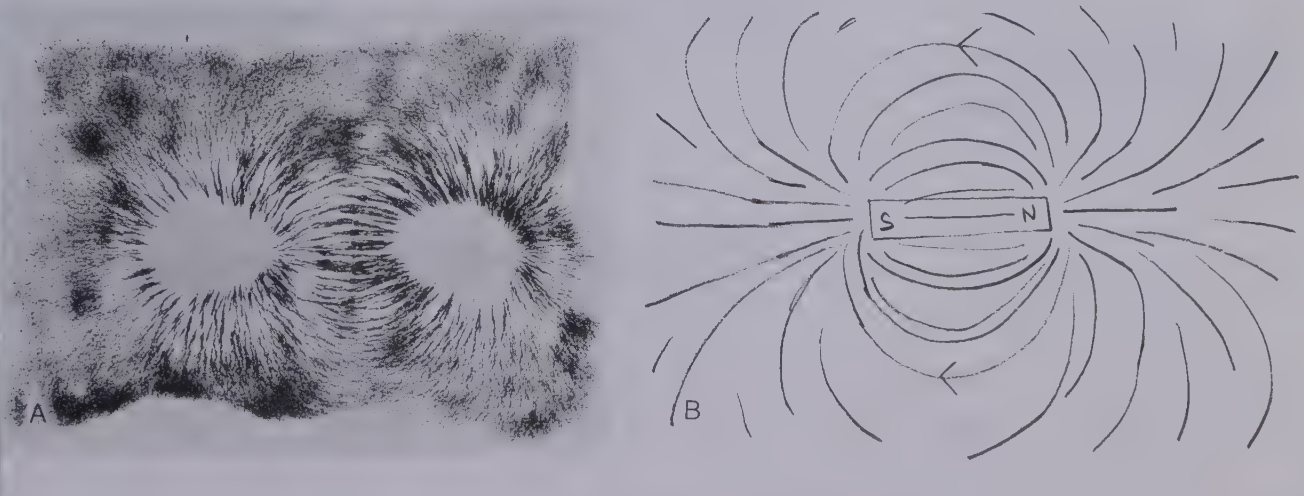
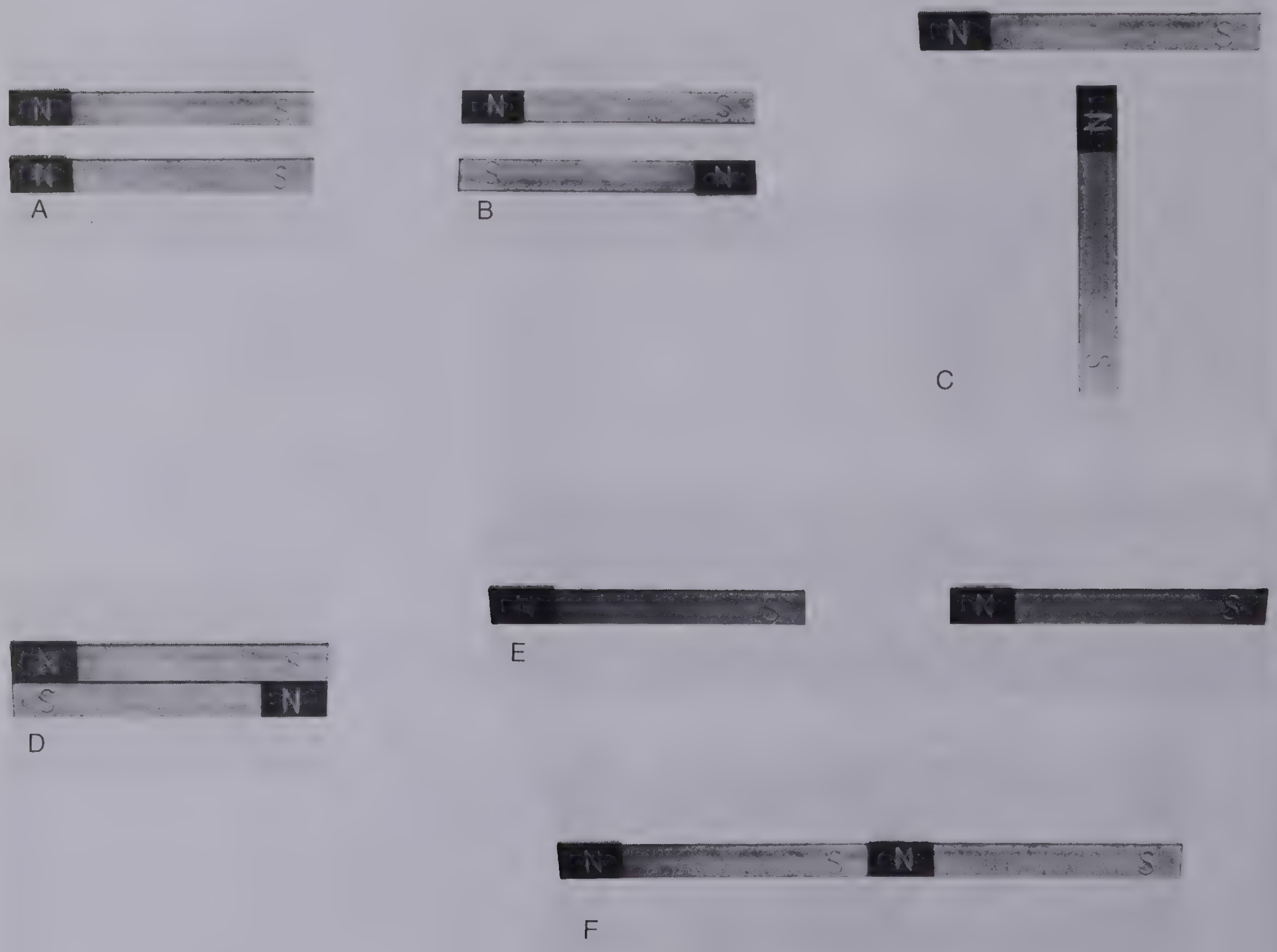


Figure 8-6 *(A) Why do the filings make a pattern? (B) Draw the field of your magnet.*

Now you are on your own. Put both magnets down under the lid. Arrange them any way you want. Figure 8-7 shows some possible arrangements. Do some of these or invent others. Make drawings in your notebook for at least two arrangements. If some of them are too big for your box lid, just do part of the field, letting the magnets stick out at the edges. Make a larger drawing of one of your arrangements for the bulletin board. ★

Figure 8-7 *Possible arrangements of two bar magnets. Try these or invent your own.*



8-6 How do magnets get that way?

Look at the iron filing maps of the field. It is impossible to pick a point in a magnet and say, ''This is the north pole.'' Instead, the pole is spread out. The poles of a magnet are where the lines made by the filings seem to comes closest together. Poles are not points; they are areas.

What happens to the poles when two magnets are very close or touching, as in Figures 8-7E and F? Study the drawings made by students who put their magnets together this way. Notice that the lines between the magnets are almost straight when the magnets are close. When the magnets touch, they look like one magnet. The poles in the middle disappear. The two magnets become one magnet with only one north and one south pole.

What would happen if you could break a magnet in two? Your teacher has one that has been broken, and will show you.

As you can see, breaking a magnet in two makes two magnets out of it. It can be broken into hundreds of pieces, and each piece will be a whole magnet.

Scientists have a theory to explain these observations. They say that a magnetic material is made of thousands of tiny magnets. Each of these tiny magnets is called a **domain.** In an ordinary piece of iron, the domains are pointing many different ways, as shown in Figure 8-8A. There are many tiny magnets, but they are not cooperating. In Figure 8-8B the domains are all lined up in the same direction. Now they are cooperating, and the piece of iron has become a magnet.

This theory also explains why dropping a magnet can spoil it. If you drop it or bang it with a hammer, you jiggle the domains so they do not line up any more.

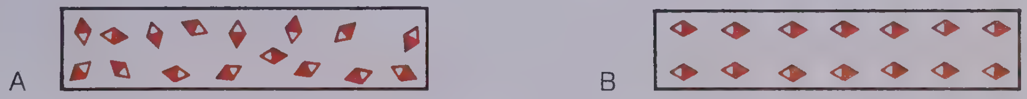


Figure 8-8 (*A*) *Domains in an unmagnetized piece of iron point in all directions. The iron is magnetic, but not a magnet.* (*B*) *Domains in a magnet.*

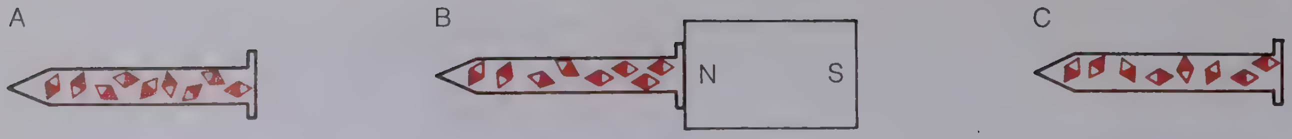


Figure 8-9 *How a magnet attracts a nail. (A) The nail is not magnetized. The domains point in many directions. (B) The N pole of the magnet attracts the S poles of the domains and repels the N poles. The force is strong enough to turn the domains around near the magnet. (C) Even when the magnet is taken away, the domains will not be as mixed up as before. The nail will be a very weak magnet. How could you mix the domains up again?*

A magnet can pick up nails even when the nails are not magnets. Study Figure 8-9 and you will understand.

To magnetize a nail or a needle or even a paper clip, stroke it with a magnet. Always stroke it in one direction only. If you go back and forth, it will not make a good magnet. Make a magnet this way and see what you can pick up or pull with it.

8-7 The strange behavior of a dipping compass

The magnet in Figure 8-10 is hung in a special way. It can move up and down like a seesaw, but not right and left. It is called a **dipping compass.** As you see in the picture, the north end of the compass points down. It would point down less in the United States.

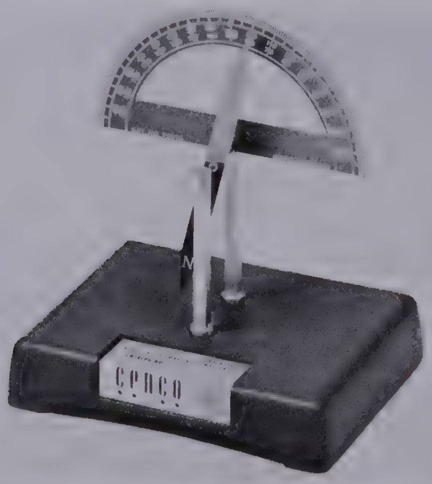


Figure 8-10 *A dipping compass.*

Imagine that you take a dipping compass and start traveling. If you go east or west, nothing much happens to the compass. If you go south, it dips less and less. Near the equator, it does not dip at all. The way the needle acts is shown in Figure 8-11.

If you go north, the needle dips more and more. Finally you find a place where the needle stands on end. This place is among the islands in far northern Canada. It is not just a spot, it is a large area.

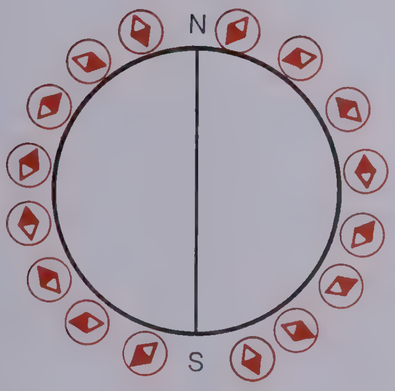
Now you go to the southern hemisphere. Here the south pole of the magnet starts to dip down. Somewhere south of Australia, near the edge of Antarctica, the needle again stands on end, with the south end down.

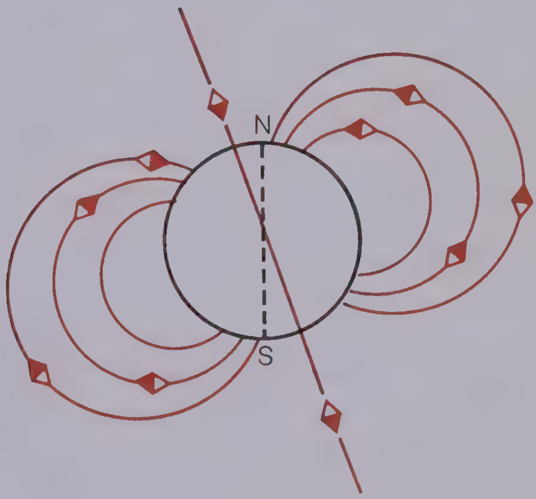
The compass needle behaves this way because the earth is a giant magnet. It has poles that attract the poles of the needle in the compass.

The pole in northern Canada is called the **North Magnetic Pole.** The one in the Antarctic is called the **South Magnetic Pole.** Notice that these poles are not at the geographic poles of the earth. The shape of the magnetic field of the earth is shown in Figure 8-12.

Figure 8-11 (*left*) *How the needle points when a dipping compass is at different places on the earth's surface.*

Figure 8-12 (*right*) *The shape of the earth's magnetic field.*





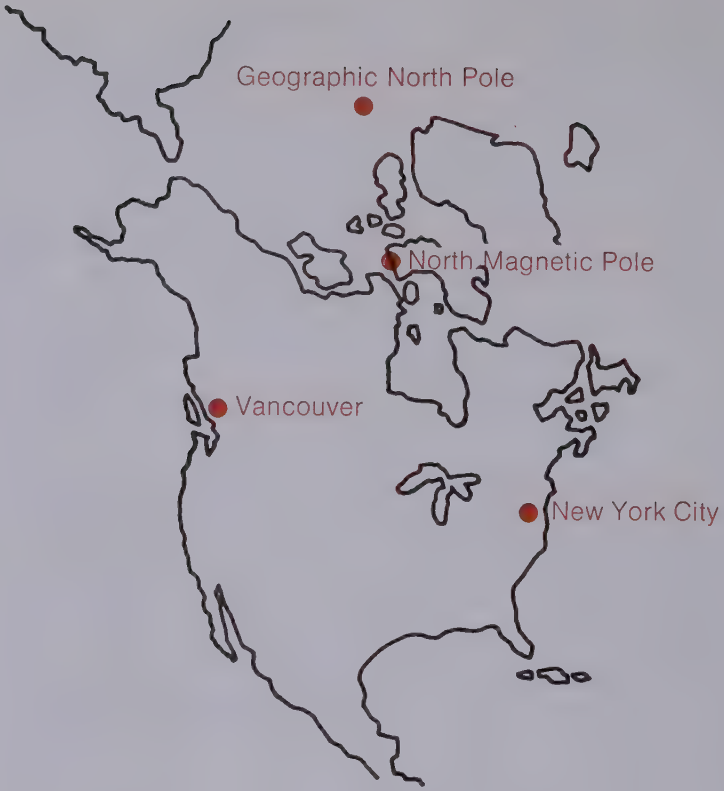


Figure 8-13 *What direction would you go to reach the North Magnetic Pole from your house?*

Here is a tricky question for you to figure out. What kind of magnetic pole (N or S) is in the North Magnetic Pole area? How do you know?

Study the map in Figure 8-13. If a compass points to the North Magnetic Pole, what direction will it point if you are in New York? if you are in Vancouver? if you are at the geographic north pole?

When you use a compass to find north, remember that it can be off a little. Of course, if you are at the geographic north pole, it will be way off, but that is no problem for most people. Wherever you live, it is probably almost correct.

In some places, the compass can be off for another reason. Whenever there is iron near it, it will not be correct. Iron deposits in the earth can change the way the compass points. So can the iron beams in a building.

Did You Get the Point?

Every magnet is surrounded by a magnetic field.

The direction of a magnetic field is the direction that the north end of a compass needle points.

Magnetic poles are areas where the lines made by iron filings come close together.

Magnetic materials are made of tiny magnetic domains. When the domains are lined up, then the material is a magnet.

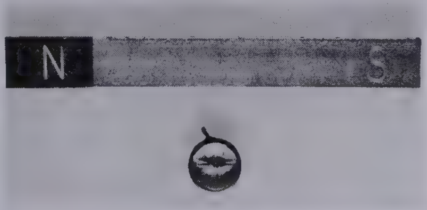
The earth is a magnet.

What Have You Learned?

1. Figure 8-14 shows a magnet and a compass needle. Why does the needle point the way it does? To answer the question, think first about what the north pole of the magnet does to the compass needle. Then think about what the south pole of the magnet does to the needle.

2. Why does stroking a nail turn it into a magnet? Why must you always stroke in the same direction? Use the domain theory in your answer.

Figure 8-14 *Magnet and compass needle for What Have You Learned?*



Magnetic Fields and Electric Currents

8-8 A compass and a current

Materials
dry cell, wire, switch, compass, cardboard with hole in center, supports for cardboard

★ Put your circuit together, as shown in Figure 8-15. Notice that the wire that comes up through the hole in the cardboard is a long, straight one. Be sure it stays straight up and down. Hold it if you have to. No other wire in the circuit should be near this one.

Before you close the switch, notice which way the compass is pointing. Arrange the cardboard so that the needle points at one of the edges. Mark that edge N as in Figure 8-16A.

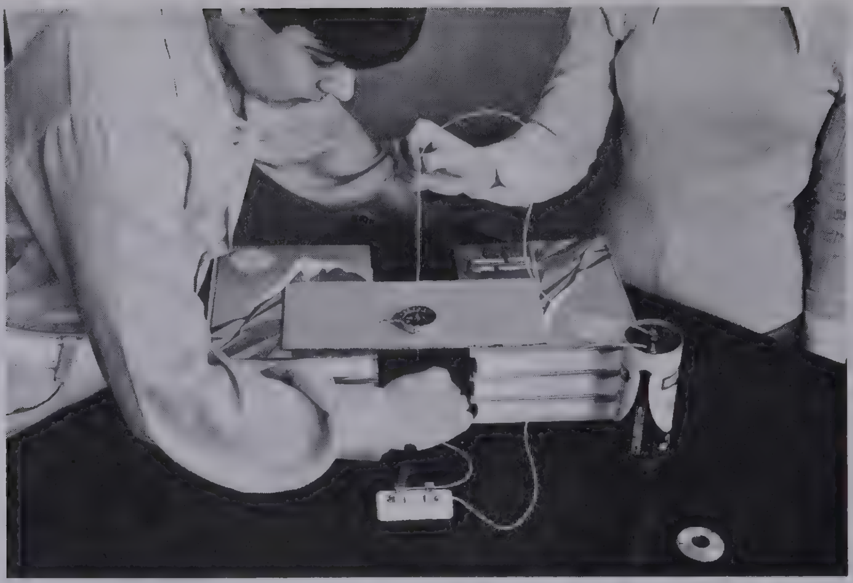


Figure 8-15 *Circuit for the activity in Section 8-8.*

In your notebook, make a drawing like Figure 8-16B. Each circle stands for one place where you will put your compass.

What you are going to do now is very bad for the dry cell. The only load in the circuit is the wire, so the current will be big. **When you close the switch, do not keep it closed for more than a few seconds.** Get everything ready, and watch the compass needle when you close the switch. See what happens, then open the switch immediately. Put an arrow on the drawing in your notebook to show how the compass points.

Repeat this for all four positions of the compass.

Look at your dry cell and decide which way electrons flow when you close the switch. Beside the drawing in your notebook, write either, "Electrons came up the wire," or, "Electrons went down the wire."

Now change the wires that are connected to the dry cell. The wire that was on the + side should be moved to the – side; the wire that was on the – side should be moved to the + side. Make a new drawing. This time the electrons will flow the opposite way. Do the whole experiment over again, and record how the compass needle points. ★

The thing that Oersted and his students discovered so long ago was what you have just discovered: *Every electric current is surrounded by a magnetic field.*

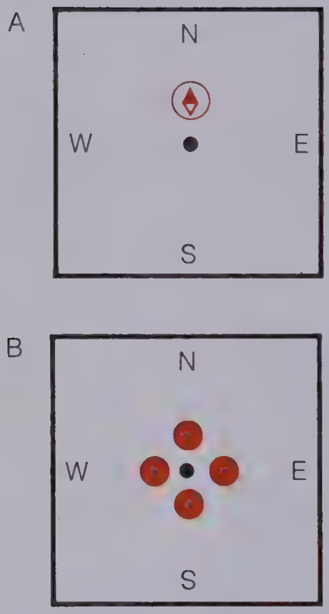
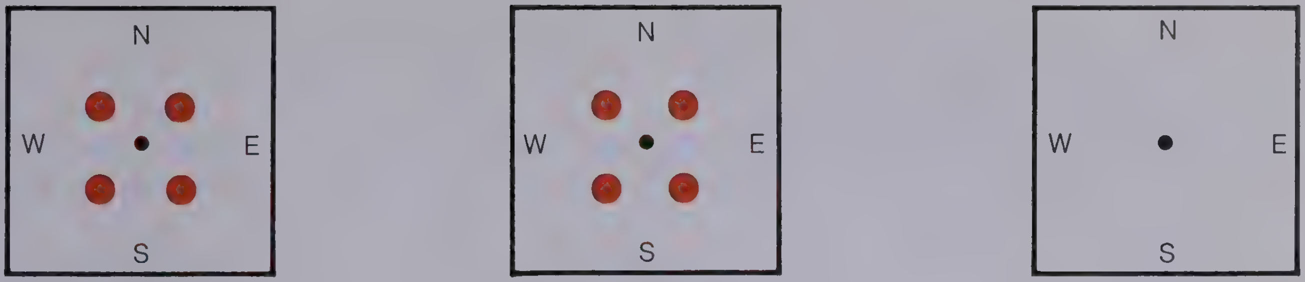


Figure 8-16 (*A*) *Make the cardboard so the directions are right when you look down at it.* (*B*) *Copy this drawing in your notebook twice. You will put your compass on top of each circle.*



A. Electrons came up the wire.

B. Electrons went down the wire.

C. Electrons came up the wire.

Figure 8-17 *Copy these diagrams in your notebook.*

★ Study your diagrams. Then copy Figures 8-17A and B. Put an arrow in each of the circles to show how the compass would point in these places. Copy Figure 8-17C and draw the shape of the field around the wire. Put arrows on the line you draw. Describe the shape in words. ★

People have made a rule for finding the direction of the field around a wire. It is this: Put your left thumb on the wire, with the thumb pointing in the direction the electrons are going (Figure 8-18). Now grab the wire with your other fingers. The fingers will go around the wire in the direction of the field. Try this with your diagrams and you will see that it works.

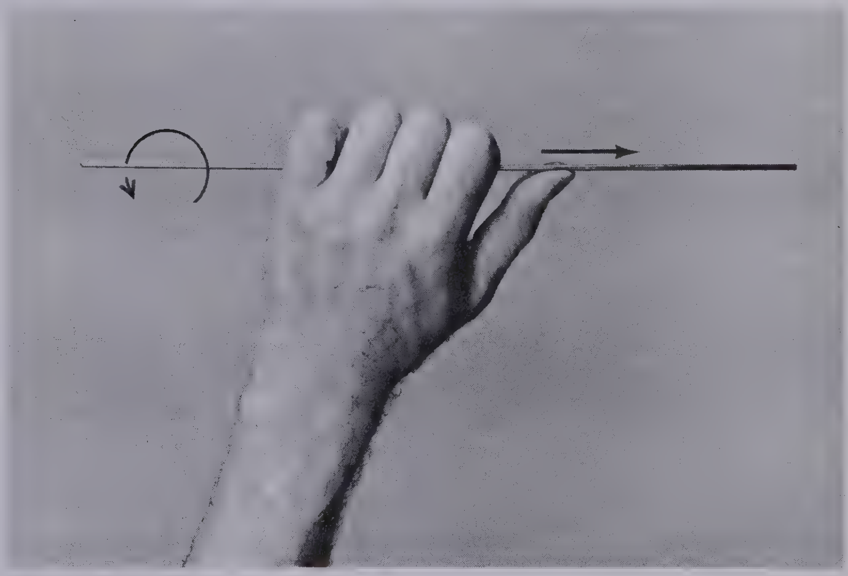


Figure 8-18 *The left-hand rule: When your thumb points the way the electrons are going, your fingers go around the wire in the direction of the field.*

8-9 How to make the field stronger

Materials
dry cell, wire, switch, compass, cardboard with hole in center, supports for cardboard, iron filings, wooden stick, soft iron rod

★ Put a small pinch of iron filings on the cardboard where you had your compass needles. Be sure they are close to the wire. Close the switch. Do the filings line up? Compare the strength of this field with the field of the magnets you used in Section 8-5.

Here are some activities to help you find out how the magnetic field around a current can be made stronger. Write your observations in your notebook.

1. Make a coil out of a long piece of stiff wire (Figure 8-19). Wind it around a wooden stick so that each turn of wire touches the next one. Connect the circuit as shown in Figure 8-20. Put a pinch of iron filings on a piece of paper. Put the coil on the paper. Will it pick up iron filings when you close the switch? Be sure to open the switch after a few seconds.

2. Take out the wooden core and try to keep your coil together without it. Put the coil down in the filings and close the switch. Will it pick up filings when you close the switch? If you are able to keep the turns of the coil as close together as when they had the wooden core, then answer this question: Does it pick up more, less, or about the same amount of filings as before?

3. Test your piece of iron to see if it is magnetized. If it picks up iron filings, hit it with a hammer until it has lost its magnetism. Then use it as a core for your coil. Does the coil pick up more, less, or about the same amount of filings as with the wooden or air cores? After you open the switch, test the piece of iron again with the filings. What do you observe?

Now make a heading in your notebook for *Conclusions,* and answer these questions:

1. Which has a stronger magnetic field, a straight wire or a coil?

2. Which kind of core makes the strongest field?

3. What happens to a piece of unmagnetized iron when it has been in the center of a coil of wire that has current in it?

Look at the three conclusions you have just written. How can they be explained? Discuss with others in the class and then write your *Interpretations* in your notebook. ★

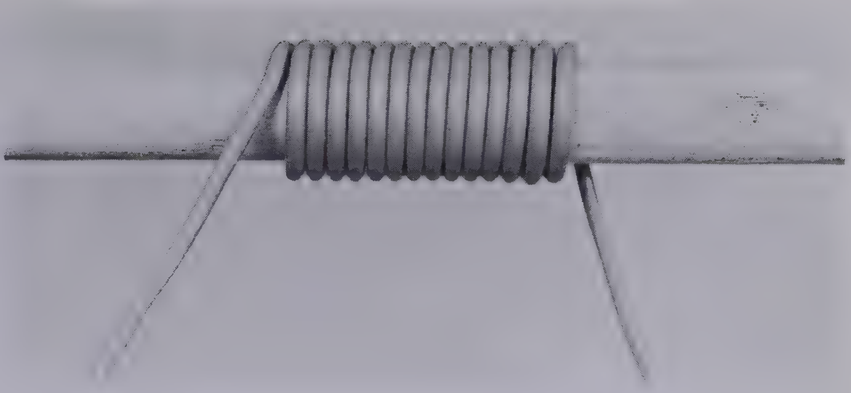


Figure 8-19 *Making a coil of wire around a stick.*

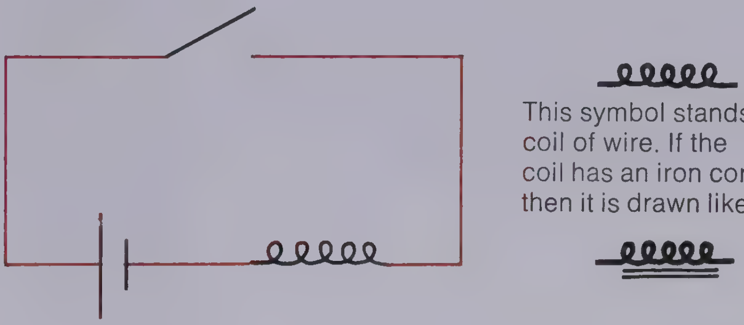


Figure 8-20 *Circuit diagram for Section 8-9.*

This symbol stands for a coil of wire. If the coil has an iron core, then it is drawn like this:

8-10 How magnets are made

A coil of wire wound around an iron core is called an **electromagnet.** The core is made of **soft iron,** which is a kind of iron that is easily magnetized by an electric current. When the current is on, the soft iron is a good magnet. When the current is off, most of the domains do not line up any more, and then the iron core is not a good magnet. A magnet made of soft iron is called a **temporary magnet.**

The magnets you used earlier in this chapter were made from steel bars. **Steel** is iron mixed with other materials. The steel bars were put in the core of a coil. The current was turned on for a few minutes, then turned off. While the current was on, the domains in the steel lined up. When the current was off, the domains stayed lined up. Steel magnets, whose domains stay lined up, are called **permanent magnets.**

Both kinds of magnet are useful. Sometimes it is important to have a magnet that turns on and off. Then an

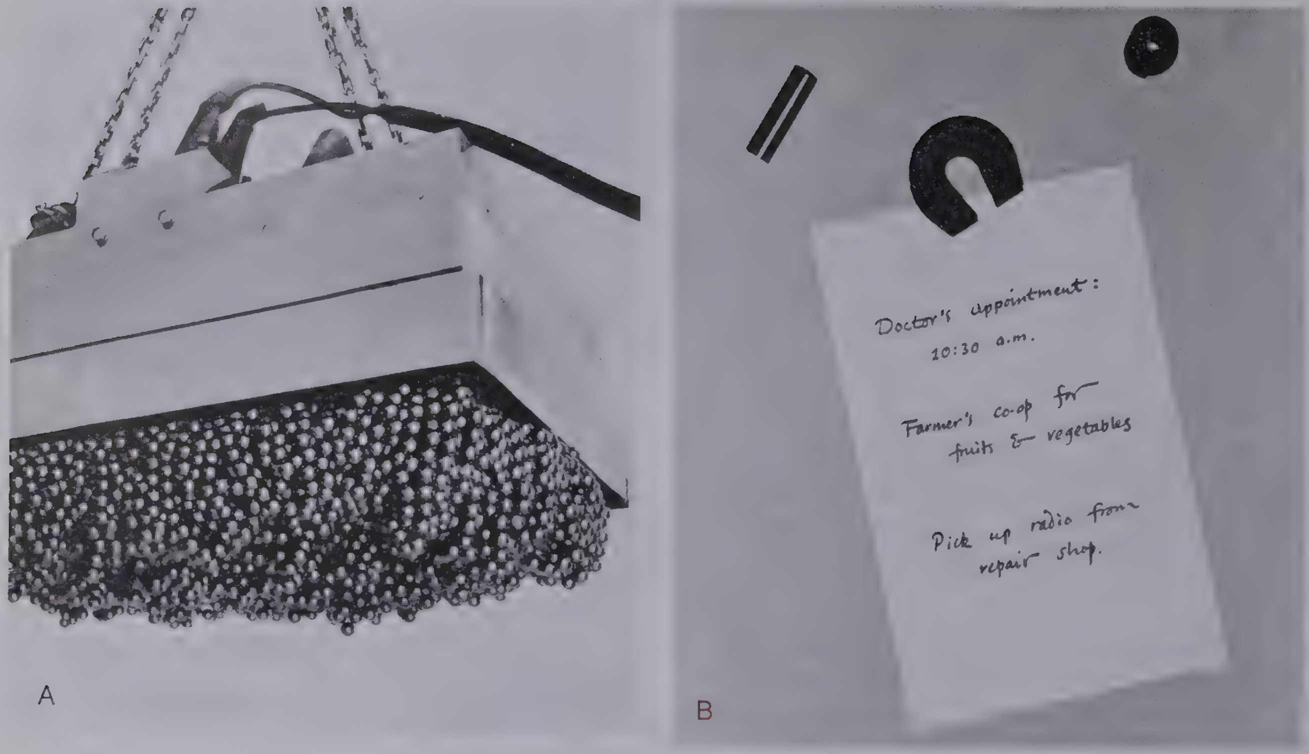


Figure 8-21 *(A) A magnet lifting ball bearings. (B) Would the magnets fall if you unplugged the refrigerator?*

electromagnet with a soft iron core is used. Sometimes it is important to have one that stays magnetized. Look at Figure 8-21 and decide which kind of magnet would be better in each case.

If you want to magnetize a screwdriver or a nail to make a permanent magnet for yourself, you can use your coil to do it.

8-11 What else will change the strength of an electromagnet?

Materials
dry cell, wire, switch, soft iron rod, paper clips

★ Does the number of turns of wire in the coil make a difference in the strength of an electromagnet? Does the size of the current make a difference? To answer these questions, divide into teams. Each team will work on one of the problems listed below. Later you will compare the results from all groups.

TELEPHONE LINEMEN AND CABLE SPLICERS

The telephone industry exists because of electromagnetism—an electromagnet inside every telephone makes it work. More than a million people work for telephone companies in this country.

Telephone linemen and cable splicers install and repair telephone lines on poles or underground. They work outdoors in all kinds of weather. Linemen string cables on poles or run them through underground pipes, leaving the ends free. A cable splicer then attaches each individual wire inside one cable to a wire in another cable. This connects telephones to the central switchboard. (A cable splicer must have good color vision—the wires in the cables are matched by a color code.)

Both men and women work as linemen and cable splicers. The telephone companies teach new employees the skills they need. They are taught in classrooms and on the job. Many men get their first training for these occupations in the army.

To test how strong a magnet is, you will count how many paper clips it picks up.

Every team: Make a coil with 10 turns of wire and an iron core, and connect it in the circuit of Figure 8-20. How many paper clips will it pick up?

Team 1: Now increase to 20 turns of wire, making the coil longer (Figure 8-22B). How many paper clips will it pick up? Repeat with 30 turns.

Team 2: Now increase to 20 turns, keeping the length of the coil the same. You do this by winding on top of the first 10 turns (Figure 8-22C). How many paper clips will it pick up? Repeat with 30 turns.

Team 3: Now stretch your coil (10 turns) until it is twice as long. How many paper clips will it pick up?

Team 4: Now increase the current by using two dry cells. Be sure to connect the – side of one cell to the + side of the other. How many paper clips will the new circuit pick up?

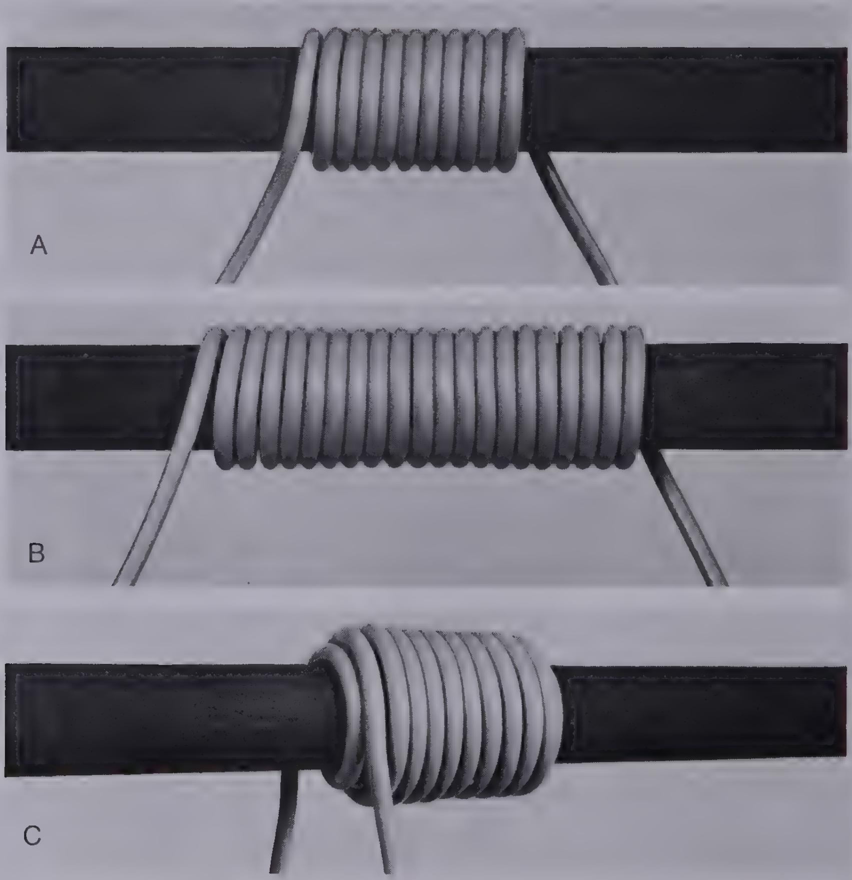


Figure 8-22 *Winding the coils for Section 8-11. (A) 10 turns; (B) 20 turns; (C) 20 turns, with second 10 turns on top of the first 10.*

Record your observations in your notebook. Report what you found to the class. Discuss everyone's observations, and write a summary. The summary will answer the question; What influences the strength of an electromagnet? Include in the summary what you learned in the activity in Section 8-9. ★

Many modern electric appliances use electromagnets. Most of the time they are hidden inside, but if you pull apart old, worn-out electric things you may find the electromagnets.

8-12 What causes magnetism?

Scientists today think that the cause of all magnetism is charges in motion, even the magnetism of a bar magnet or the earth.

Here is how they explain the magnetism of a bar magnet. They know that all matter contains electrons. The electrons are in motion. Every moving electron is surrounded by a tiny magnetic field. If two electrons move in opposite ways, then the fields are opposite and cancel each other out. This is what happens with most materials such as wood, copper, stones, air, glass, and plastics. But for a few materials, some of the fields do not cancel. The electrons cooperate to make a good field. This seems to be true of iron.

Why is the earth a magnet? About halfway to the center of the earth, a part of the core is probably melted iron and nickel (Figure 8-23). Scientists think that the liquid metal is slowly moving, carrying charges along as it goes. The moving charges are therefore surrounded by a magnetic field.

Did You Get the Point?

Every electric current is surrounded by a magnetic field.

The field around a straight wire is circular. The direction can be found from the left-hand rule.

An electromagnet is a coil with a soft iron core. It can easily be turned on and off.

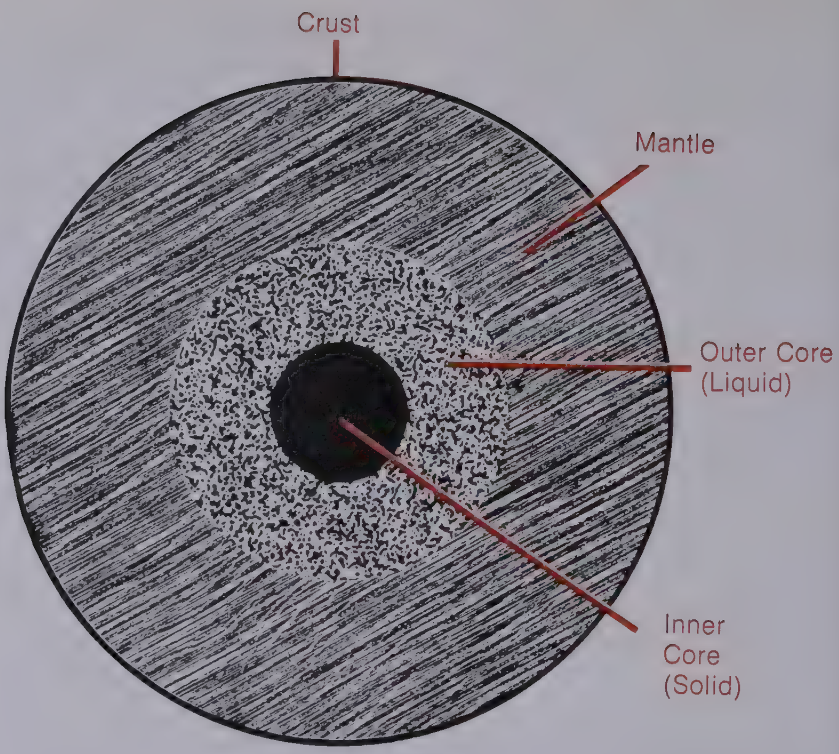


Figure 8-23 *The magnetism of the earth is probably caused by charges moving in the outer core.*

The strength of an electromagnet depends on the kind of core, the number of turns per centimeter of length, and the size of the current.

All magnetism is caused by charges in motion.

The magnetism of a bar magnet is caused by the motion of electrons.

The magnetism of the earth is probably caused by charges in motion in the liquid part of its core.

What Have You Learned?

Each sentence below has a word missing. The dashes tell how many letters the word has. On another sheet of paper, write each of the missing words. Put a circle around the letters where circles are around the dashes. The letters in the circles will spell the name of something important you have been studying in this chapter.

1. Every electric current is surrounded by a magnetic – – ⊖ – –.

2. Imagine that a wire comes up toward you out of this page. Electrons travel up the wire. At the bottom of the page the magnetic field is toward the ⊖ – – –.

3. An iron – – – ⊖ makes an electromagnet strong.

4. The shape of the field around a straight wire is a – – – ⊖ – –.

5. A magnet can be turned on and off easily if it has a core made of – – – ⊖ – – – –. (two words)

6. One way to make an electromagnet stronger is to increase the – – ⊖ – – – –.

7. When a straight wire is bent to make a – ⊖ – –, the magnetic field will be stronger.

8. A – – – ⊖ – – – – – – magnet cannot be turned on and off.

9. All magnetism is caused by – – ⊖ – – – – in motion.

10. The – – – – – ⊖ – – of an electromagnet depends on the number of turns per centimeter.

11. An electromagnet is used when a person wants to be able to turn the magnet – ⊖ – – – – – –. (three words)

12. The magnetism of the earth is probably caused by charges moving in the – – – ⊖.

13. It does not strengthen an electromagnet to wind more ⊖ – – – – of wire on the core unless they are wound on top of each other.

SKULLDUGGERY

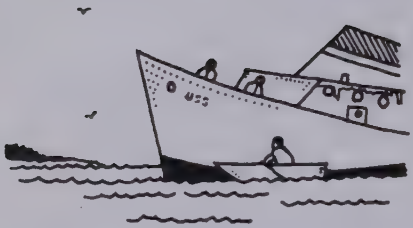
A science fiction story:

Juan lived on an island in the ocean near the equator. One day he found a boat on the beach. No one seemed to own it, so he decided to use it. It was a dirty metal boat, and he thought it was aluminum. What he did not know was that it was made of iron and was a very powerful magnet.

Because the boat was a magnet, he had some very strange adventures. You can find out what they were by filling in the correct word whenever you come to a blank. Do not write in the book. Instead, make a list with numbers from 1 to 22 and write the words on that.

The first thing that Juan noticed was that whenever he was out paddling the boat he had no trouble making it go north. However, when he tried to turn it around to go south, he had to use all of his strength. Of course, this was because the front end of the boat was the (1) pole of the magnet.

One day he was paddling east, but the front end of the boat kept swinging around toward the (2) because it was trying to line itself up with the earth's (3) field. The boat was acting like the needle of a (4).



Suddenly a huge ocean liner came by. A liner is made of steel, so Juan's boat was (5) to it. Soon the small boat was stuck fast to the side of the liner. The front end of Juan's boat was a (6) magnetic pole. Where this end of the boat touched the liner, the (7) in the iron of the ship turned so that their (8) poles were next to Juan's boat. Then the boat and the liner stuck together because (9) magnetic poles attract each other.

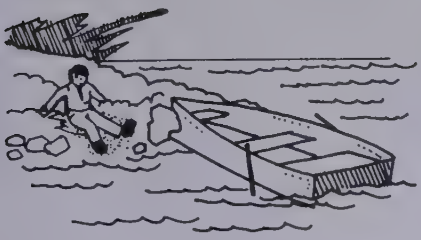
At the other end of Juan's boat was a (10) magnetic pole. Next to it the (11) in the liner turned their (12) poles toward the little boat.

Juan was quite surprised by what was happening, because he had thought his boat was made of aluminum. He went on board the big ship and the captain explained magnetism to him. Then the captain sent for a tugboat to pull Juan's boat away.

Now that Juan knew his boat was a (13) he decided he would try to find the North (14). He knew he would have no trouble finding it. All he had to do was go in the direction the (15) of his boat pointed.

It took a long time and the weather got pretty cold. Finally, the (16) end of the boat started to stick up out of the water. Then Juan knew he was getting near the (17). The boat tipped more and more until it was almost up on end. Juan was afraid that the boat would be pulled under the water.

Then he noticed that the boat was heading for an island. It went faster and faster. "The (18) of the earth must be very strong here," said Juan. Then the boat crashed into the island. Juan



fell out onto a snow bank, so he was not hurt. The boat had a dent in it, but it looked all right.

Juan went to push his boat back into the water. He thought it would be hard to lift the end that was attracted to the (19) of the earth and easy to lift the other end. However, both ends were easy to lift. Then Juan knew that his boat was not a (20) any more. The crash had mixed up the (21) and they were not lined up any more.

Of course, now that the boat was not a magnet, he could not use it for a (22) any more. But the sun was shining, so he paddled home by watching the sun in the daytime and the North Star at night.

FOR FURTHER READING

Corbett, Scott. *What Makes a Light Go On?* Boston: Little, Brown and Company, 1966. Detailed pictures explaining current, magnetism, and static electricity.

Fink, Donald G., and David M. Lutyens. *Physics of Television.* Garden City, N.Y.: Doubleday and Company, Inc., 1960. A clear, basic explanation of how a television works.

Lieberg, Owen S. *Wonders of Magnets and Magnetism.* New York: Dodd, Mead and Co., 1967. Discusses properties of magnetic substances, principles of attraction and repulsion, and magnetic fields.

WHAT'S NEXT?

Did you ever feel a nail after you pulled it out of a board? It is quite warm. The needle of a sewing maching can get hot enough to hurt your finger when you touch it. Why does this happen? You will find out in the next chapter.

Unit Four

Other Forms of Energy

Chapter 9

Heat and Temperature

Heat affects everybody's life in one way or another.

You can lie on the beach in the hot sun and wind up with a beautiful tan. Or a beautiful sunburn. Or you may not get to the beach at all because the heat made your car's radiator boil over. You use heat to cook your food, but, unless you have pots and pans with special handles, you may cook your fingers too. Heat keeps your home comfortable in winter, but if someone is careless it can burn your house down.

The grinding machine in the photo turns so fast that it gets very hot, so water is used to cool it off.

Fire was one of our first tools. Since we discovered how to make fire, we have been looking for new ways to use—and to control—heat. It is still one of our most efficient tools, and one of our most dangerous. The more we understand it, the more useful and the less dangerous it will be.

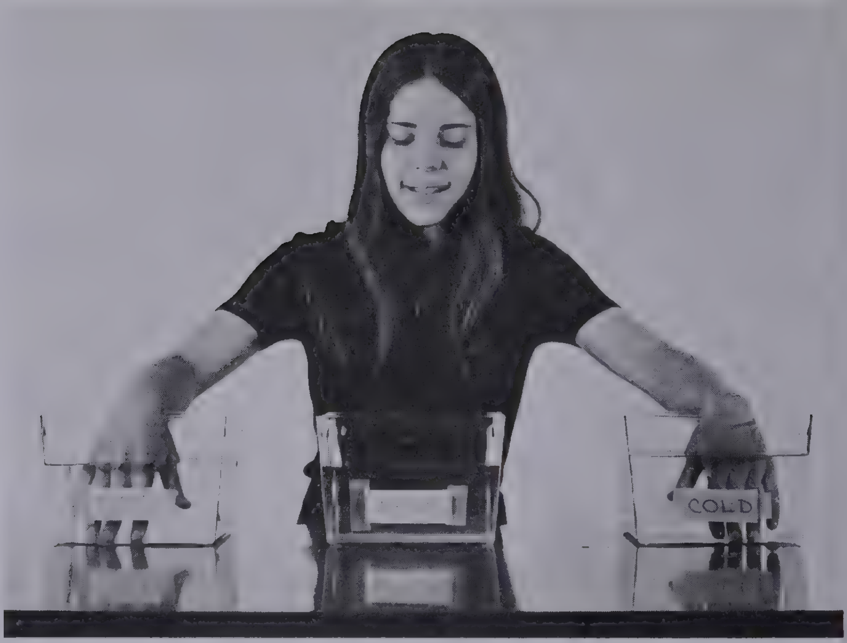


Figure 9-1 *Don't hurry! Getting your hands used to the temperature of the water takes a little time.*

Heat and Temperature

9-1 Can you tell the temperature?

Did you ever come into the house on a winter day and say, "Boy, it's hot in here"?

Then your mother says, "And I thought it was cold."

Are people any good at telling the temperature? Here is an experiment to test yourself.

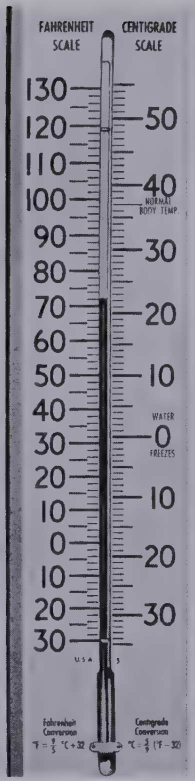
Materials
3 pans, hot and cold water

★ Get three pans of water, one quite hot, one quite cold, and one lukewarm. The hot one should be hot to touch, but not uncomfortable. Put one hand in the hot water and one in the cold water, as you see in Figure 9-1. Count out loud, not too fast, to 25. Then take the hand from the hot water and put it in the lukewarm water. Keep the other hand in the cold water. How does the lukewarm water feel?

Now take the other hand from the cold water and put it in the middle pan. What does that hand tell you about the temperature of the water? ★

Use this experiment to explain why you and your mother might disagree about how hot the house is.

Figure 9-2 *What temperature is your classroom today in degrees Fahrenheit? In degrees Celsius? Centigrade is an older name for the Celsius Scale.*



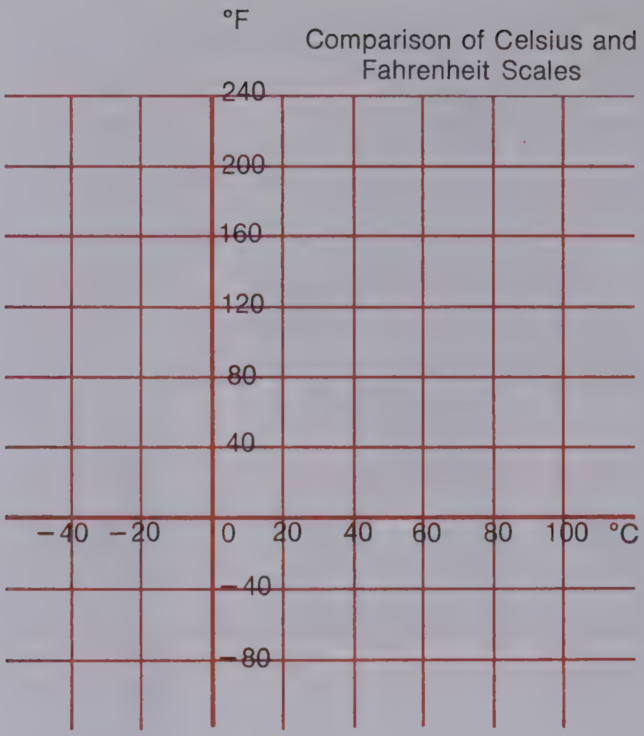
9-2 There are different temperature scales

When you are sick, someone may take your temperature. If you live in England or France or Mexico or most of the countries of the world, your mother will be happy if the thermometer says 37°. But an American knows that a normal temperature is 98.6°. Are Frenchmen or Mexicans colder than people in the United States? Of course not. They just use different temperature scales.

The two scales are shown in Figure 9-2. The **Fahrenheit** (FAIR-en-hite) scale is used in the United States. On this scale, the boiling point of water is 212°F and the freezing point is 32°F. The little circle after the number means *degrees.* A **degree** is a unit of temperature. The F stands for Fahrenheit.

The **Celsius** (SEL-see-us) scale is used in almost all of the countries of the world. England has recently changed to this system, and Canada may soon. On this scale, the boiling point of water is 100°C and the freezing point is 0°C. A Celsius degree is larger than a Fahrenheit degree.

Figure 9-3 *Make a graph like this to compare temperature scales.*



Materials
graph paper, pencil, ruler

★ There is an easy way to change from one scale to the other. Make a graph. Figure 9-3 shows how to mark the axes of the graph. Locate the freezing point of water on the graph (0°C and 32°F). Then locate the boiling point (100°C and 212°F). Connect these points with a straight line. Continue the line past the points in both directions. Now, whenever you want to change scales, all you have to do is read the graph. ★

Here are a few problems to try for practice. Use your graph to find your answers. Then look up the answers on page 190 to see if you are correct.

1. A room is at 68°F. What is the Celsius temperature?
2. On a hot summer day, the temperature is 104°F. What is this in Celsius degrees?
3. The afternoon temperature in Paris is 30°C. Is it more likely to be a winter or a summer day?
4. What temperature is the same on both scales?

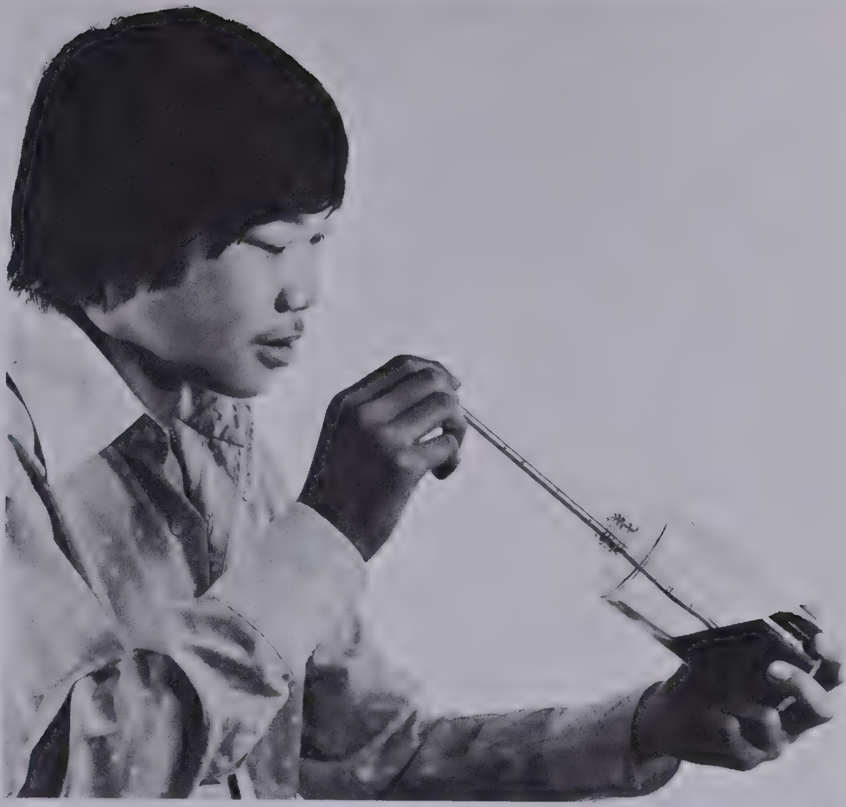


Figure 9-4 *How to measure the temperature of lead shot.*

9-3 Work can raise the temperature

Materials
bottle, lead shot, thermometer

★ The student in Figure 9-4 is measuring the temperature of the lead shot in a bottle. Notice that he has tipped the bottle so that the shot covers the end of the thermometer. Do this carefully so that you do not spill the shot or break the thermometer. Watch the thermometer until you are sure it is not changing. Then record the temperature in your notebook. Use a chart like the one in Figure 9-5. Write the temperatures in °C or °F, depending on the kind of thermometer you use.

Figure 9-5 *Use a chart like this to record the temperature of the shot.*

	temperature of shot
Before shaking bottle	?
After first 100 shakes	?
After second 100 shakes	?
After third 100 shakes	?
After fourth 100 shakes	?

Now screw the top tightly on the bottle. You are going to do some work on the bottle and the shot. Shake the bottle up and down. On each shake the shot should move to the top of the bottle and then fall down. Shake it rapidly 100 times. Then measure the temperature of the shot again. Record it in the chart.

Another student in your group should immediately shake the bottle 100 times more. Repeat this until there are at least four records in your chart of temperatures after shaking.

What happens to the temperature of the shot when it is shaken?

How do you interpret this result?

How much did the temperature change each time the bottle was shaken? ★

9-4 Heat is energy

Answers to questions on page 188

1. 20°C
2. 40°C
3. 86°F, summer
4. −40°

If you put a metal spoon in a pot on the stove, pretty soon you feel the handle getting hot. Heat seems to flow from one end of the spoon to the other. Because of this, people used to think that heat was a fluid going from hot places to cold places.

But things get hotter when you rub them, too. Where could the heat fluid be coming from here?

Experiments like the one you did with the lead shot changed people's ideas about heat. In that experiment, every time you shook the bottle a hundred times, the temperature went up almost the same amount. Of course your measurements are not very accurate. But hundreds of better measurements have shown that a certain amount of work always gives about the same increase in temperature.

Today all scientists believe that **heat** is a kind of energy. Kinetic energy is changed into heat energy when things rub together. Heat energy can also be changed into kinetic energy. This is what happens in the engine of a car. Think of other examples of heat energy changing into kinetic energy.

9-5 Heat and temperature are not the same thing

Materials
2 beakers, stirring rod, thermometer, 2 stands, 2 heaters

★ Figure 9-6 shows two beakers of water being heated. Your teacher will help you to arrange the same experiment. Fill one beaker with water. Stir it well. Then pour a small amount of it into the other beaker. Measure the temperature of the water in each beaker. They should be the same. Record the temperature in your notebook.

Now start to heat them at the same time. After two minutes, take the beakers away from the heat and measure the temperatures again. Record them in your notebook.

Have the two beakers of water taken in the same amount of heat? How do you know this? Did the two beakers have the same temperature at the end? ★

Heat is a form of energy. It takes more heat to warm up a lot of water than it takes to warm up a little water. **Temperature** tells how hot something is, not how much energy has been used to make it hot. Later you will learn another definition for temperature, but this one will do for now.

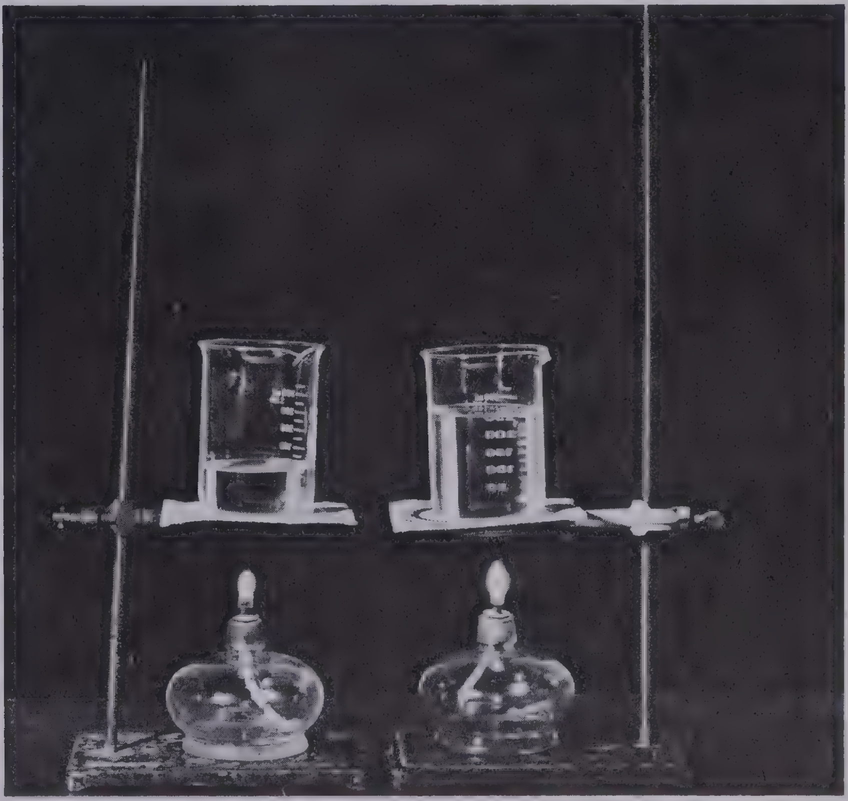


Figure 9-6 *Will one beaker of water get hotter than the other?*

Figure 9-7

material	calories needed to warm up one kilogram one Celsius degree
water	1000
aluminum	210
copper	93
glass	160
rock	180 to 210
sand	190
wood	420

Heat energy is measured in calories. A **calorie** (abbreviation, **cal**) is the amount of heat needed to raise the temperature of one gram of water one Celsius degree.

If you are worried about your weight, you might say, "I have to count my calories." This is because you get your energy from your food. In your body, some of the energy of food is changed into heat to keep you warm. Some is changed into kinetic energy when you move. Food energy is counted in kilocalories (kcal). A **kilocalorie** is 1000 calories. A kilocalorie is also the amount of heat needed to raise the temperature of one kilogram of water one Celsius degree. Some people say *calories* when they mean *kilocalories,* but only when they are talking about food.

It takes more calories to heat up a kilogram of water one Celsius degree than to heat up a kilogram of most other materials. See Figure 9-7.

Did You Get the Point?

Heat is a form of energy.

Kinetic energy can be changed to heat energy, and heat energy can be changed to kinetic energy.

A calorie is the amount of heat needed to raise the temperature of one gram of water one Celsius degree.

Temperature tells how hot something is, not how much energy has been used to make it hot.

Temperature can be measured on the Celsius or the Fahrenheit scale.

What Have You Learned?

1. Which of the scales, Celsius or Fahrenheit, belongs to the metric system? Why do you think so?

2. If someone said, "It's pretty warm out, 30°," which scale would he be using?

3. Why does a nail feel hot when you have just pulled it out of a board?

4. A glass of water holds about 200 g. How many calories does it take to warm up 200 g of water one Celsius degree? How much to warm it up 10 Celsius degrees? How many kilocalories is that?

5. Two pans of water are at 25°C. One has much more water than the other. Both are put on the stove at the same time. They start to boil at the same time. Did they get the same amount of heat?

6. In winter, the land gets colder than the ocean. Find the reason why in Figure 9-7.

Particles Help to Explain Heat and Temperature

9-6 Observe carefully

Here are some small experiments. Your job is to observe very carefully what happens in each one. Later you will interpret the observations.

You do not have to do the experiments in order. To keep your notes straight, put the number of each experiment beside your observations.

Materials
smelly substance, watch

★ 1. Someone will spray a small amount of a smelly substance into the room. At the same time, someone with a watch will start counting seconds: "0, 1, 2, 3, . . ." When you smell it, write down how many seconds it took for the smell to reach you. Later measure how far away you were from the place where the spraying was done. Then figure out the speed. Remember:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

Materials
flask, stopper, glass tube, beaker, ringstand, clamp, ice or snow

2. Observe the equipment shown in Figure 9-8A. Warm the round part of the flask with your hands. What happens to the water in the tube? Cool the flask with snow or ice or by putting a little water on the outside and blowing on it. What happens to the water in the tube?

Materials
can or beaker, strip of cloth

3. Put about an inch of water in the bottom of a can, as shown in Figure 9-8B. Hang the strip of cloth over the side of the can. One end of the cloth must be in the water. Watch what happens immediately. Check it again four or five times during the period.

Materials
glass, food coloring

4. Fill a glass with water. Put one drop of coloring into the glass of water (Figure 9-8C). Watch what happens at first, and check it several times during the period.

Materials
dish, narrow tube

5. Put the narrow end of a glass tube into the colored water (Figure 9-8D). Be careful not to break the tip of the tube. Watch what happens to the water. ★

9-7 Some ideas about particles

How can these observations be interpreted? After watching many things like this, scientists came up with some hypotheses. They are listed below. Read them over. Then use the hypotheses to interpret what you observed.

1. All matter is made of tiny particles. The particles are too small to be seen (but not as small as the electrons and protons you learned about in Chapter 6).
2. The particles are moving all the time. When the temperature goes up, they move faster.
3. In a gas, the particles are far apart compared with their size.
4. In a liquid, they are much closer together, but are able to slide around.
5. In a solid, they are usually a little closer than in a liquid. They cannot slide around. They stay in one place, but they are moving. They vibrate in that one place.

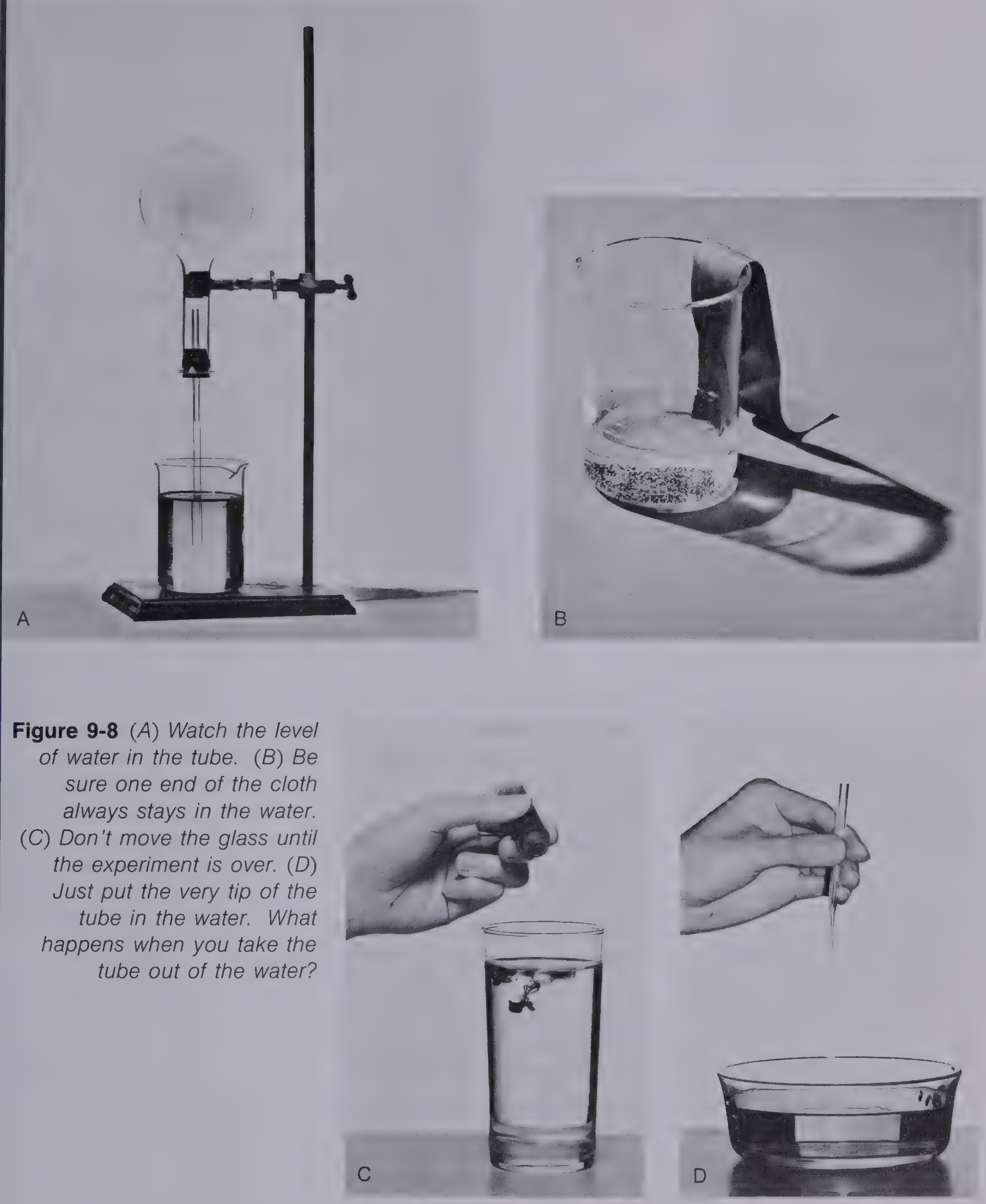


Figure 9-8 (*A*) *Watch the level of water in the tube.* (*B*) *Be sure one end of the cloth always stays in the water.* (*C*) *Don't move the glass until the experiment is over.* (*D*) *Just put the very tip of the tube in the water. What happens when you take the tube out of the water?*

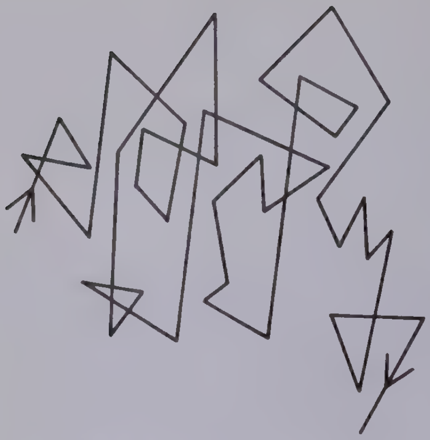


Figure 9-9 *Each particle of air goes in a straight line until it bounces off something. After a little time the path could look like this.*

6. Particles attract each other very little when they are far apart. They attract each other very much when they are close together.

Go over each of your observations. Use these hypotheses to explain what happened.

9-8 The moving-particle theory explains many things.

The hypotheses listed in Section 9-7 are part of a theory. You could call it the moving-particle theory. Here is how the theory explains some of your observations.

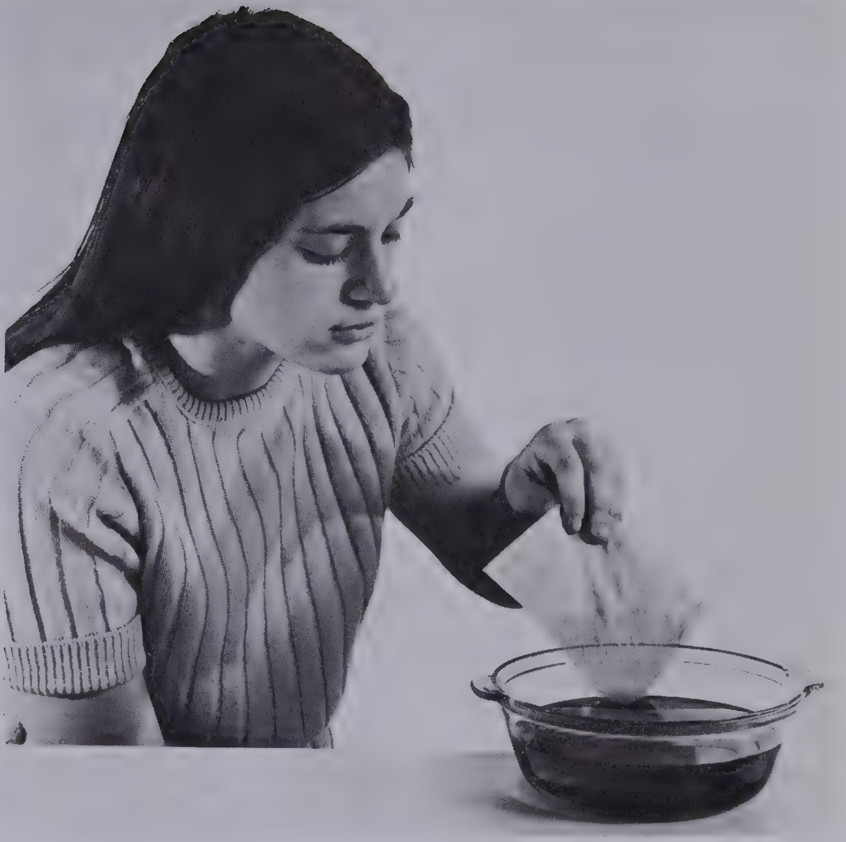
In the first experiment, the spray turned the smelly liquid into a gas. Air particles are far apart and in motion. So are the particles of smelly gas. They bump into each other. The smelly particles bounce back and forth and slowly reach all parts of the room. If you could watch one of them, it might have a path something like the one in Figure 9-9. This is why it may have taken a whole minute for the smell to reach you.

Later, when you put coloring in the water, almost the same thing happened. The water particles were moving. So were the dye particles. They slid past each other and slowly mixed. In the air, the smell might have mixed through the whole room in two minutes. How long did it take for the mixing in the small amount of water in the glasses? The mixing was faster in the air because of the big spaces between air particles.

When the air in the flask (Figure 9-8A) was warmed by your hands, the particles moved faster. They bumped into the top of the water harder than before. This pushed the water down. When the air cooled, the particles slowed down. They did not push as hard, so the water came up.

Water climbs up into tiny tubes like the one shown in Figure 9-8D. This is because the glass particles attract the water particles. Water particles also attract each other. Therefore, the particles that do not touch the glass are held up by the ones that do. If the tube is too wide, there are too many water particles in the middle of the tube, not

Figure 9-10 *Try this with different brands of tissues.*



touching the glass. So the water particles that are touching the glass cannot hold them all up. Therefore, the water cannot climb as high.

Water climbed up the cloth because there are tiny spaces between the threads. These spaces are like tiny tubes. In a paper towel there are tiny tubes too, and water will climb up them. Try holding a tissue in a dish of colored water. Watch the water rise (Figure 9-10). Later, in Chapter 15, you will learn how a piece of paper can be used like this to tell what chemicals are in the water.

9-9 What is temperature?

Particles in motion have energy—kinetic energy. What happens to the energy when particles in the air bump into each other? Here is a way to find out.

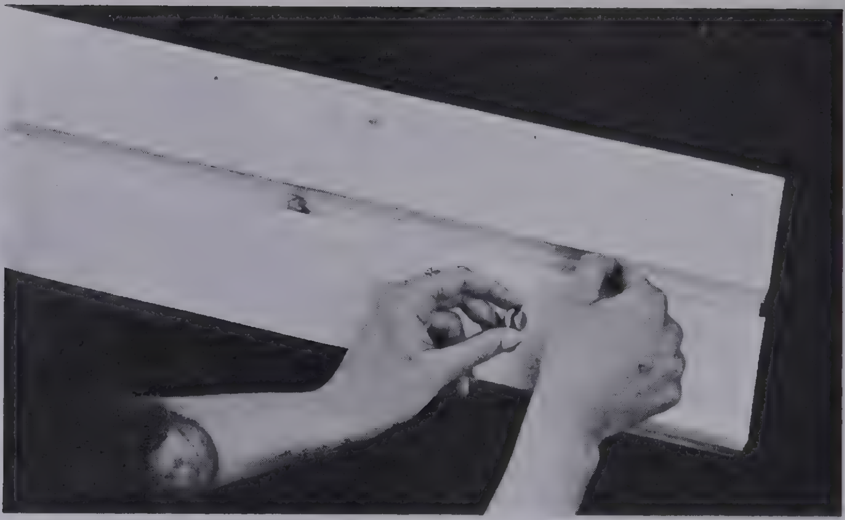


Figure 9-11 *Roll the second marble after the first.*

Materials
marbles (2 alike, 1 different), groove to roll them in

★ Take two marbles that are alike. Roll one marble slowly in a groove (Figure 9-11). Then right after it, roll the second marble faster. What happens? what happens if you roll the marbles toward each other? Try this again with two marbles of different sizes. ★

Every time the marbles bump into each other, they exchange some kinetic energy. Usually one speeds up and the other slows down.

This sort of thing is happening in the air all the time. Air particles bump into each other, exchanging kinetic energy. After the collisions, some go faster and some go slower. In the air of your room right now, some particles have a lot of kinetic energy. Others have very little.

When you talk about temperature, you are talking about the average of these kinetic energies. When the temperature goes up, the particles move faster. Some are slower than others, but the average kinetic energy is greater. When the temperature goes down, the average kinetic energy goes down. In Section 9-5 the definition of temperature was how hot something is. Now you have a better one. **Temperature** measures the average kinetic energy of the particles of a substance.

Did You Get the Point?

All matter is made of tiny particles that are moving.

They are far apart in gases, close together in liquids and solids.

In liquids they can slide around. In solids they vibrate in place.

Particles attract each other when they are close together.

As they move, particles bump into each other and exchange kinetic energy.

If the average kinetic energy of the particles is high, the temperature is high.

If the average kinetic energy of the particles is low, the temperature is low.

What Have You Learned?

Use the moving-particle theory to answer these questions.

1. A stick of wood is made of many particles. Why doesn't it fall apart?

2. When a bridge is made, the workmen may put a strip of bent metal between the bridge and the road (Figure 9-12) because the concrete expands in hot weather. Why does it expand?

3. How could you use the expansion idea to get the lid off a jar of jam?

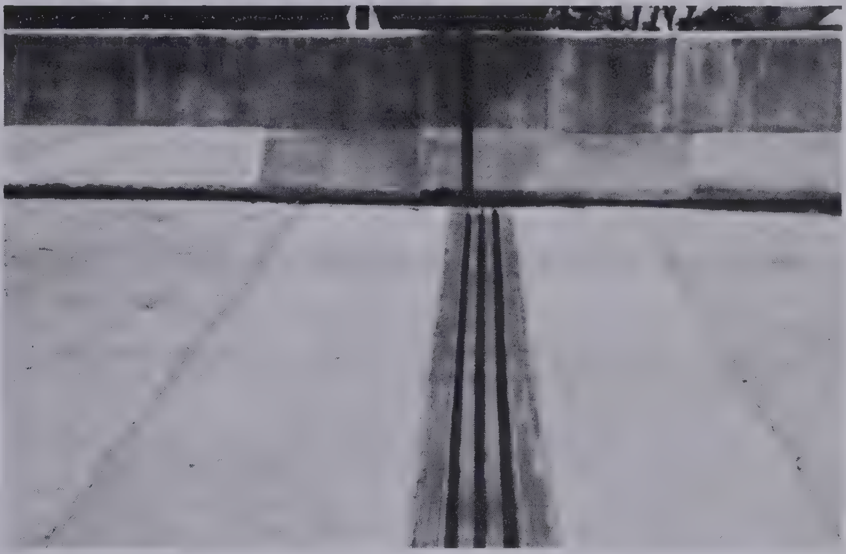


Figure 9-12 *Look for expansion joints like these in roads and bridges.*

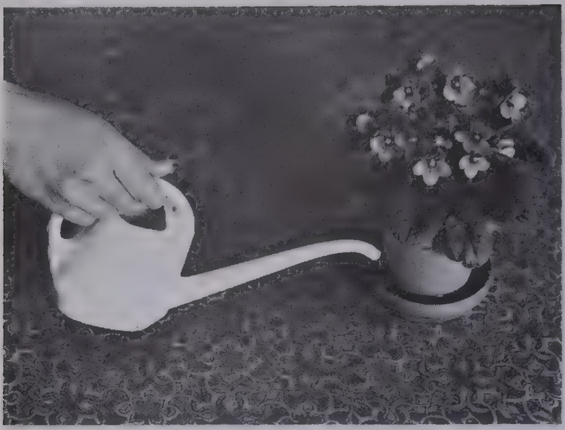


Figure 9-13 *Not all plants should be watered this way.*

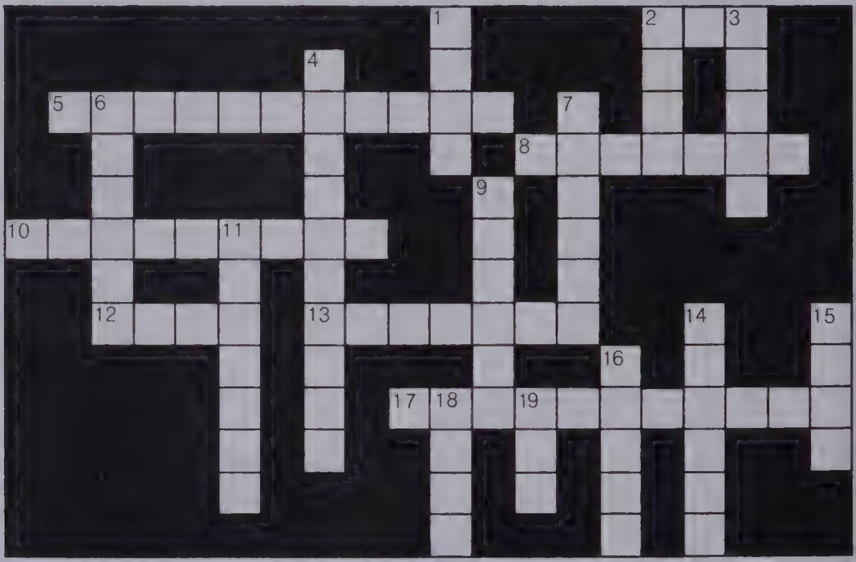
4. If you mix a cup of hot water and a cup of cold water, the temperature of the mixture is in between. Why?

5. A plant in a flower pot sits in a dish. The person who waters the plant may put the water in the dish (Figure 9-13). How does the water get to the roots of the plant?

6. When you blow up a balloon, what makes it stretch out in all directions?

SKULLDUGGERY

Your teacher will give you a copy of this crossword puzzle. Do not write in the book.



Across

2. The particles in a ____ are very far apart.
5. This goes up when the average kinetic energy of particles goes up.
8. A kind of energy that often changes to heat.
10. Tiny things, always moving.
12. What you do at a school football game.
13. Water boils at this temperature on the C scale.
17. This is used to measure temperature.

Down

1. Water freezes at this temperature on the C scale.
2. Where has the work ____ when you rub your hands?
3. In a ____ particles vibrate in place.
4. Water freezes at 32 degrees on this scale.
6. Moving things have kinetic ____.
7. Particles in a ____ slide past each other.
9. A ____ on the F scale is smaller than one on the C scale.
11. Water boils at 100 degrees on this scale.
14. The idea that everything is made of tiny moving particles is a ____.
15. When you rub your hands together you do ____.
16. At 212°F, water ____.
18. ____ is a kind of energy.
19. When two things ____ together, the energy changes to heat.

FOR FURTHER READING

Adler, Irving. *Hot and Cold.* New York: The John Day Company, Inc., 1959. Nature, measurement, and uses of heat. Relation of heat to motion and electricity.

Meetham, A. R. *The Depth of Cold.* New York: Barnes and Noble, Inc., 1967. Nature and effects of low temperature in everyday life and science and technology.

Ruchlis, Hy. *Bathtub Physics.* New York: Harcourt Brace Jovanovich, Inc., 1967. Includes brain teasers and experiments on boat sailing, bubble blowing, and splashing.

WHAT'S NEXT?

Heat is one form of energy. Sound is another. How does a sound go from a trumpet to your ear? What is a sound wave like? A special tube something like a TV tube can show graphs of sound waves. In the next chapter you will see what the graphs look like. Maybe you will be able to see a graph of your own voice on the tube.

Chapter 10

Sound and Waves

"Did you see your voice today?" asked Don.

"No, I played the harmonica," said Helen.

"And when Joe played his trumpet the picture was wild," said Bob.

"What are you kids talking about?" asked Bob's father, Mr. Grant. "How can you see your voice?"

"Well, we had a mike, and we made noises into it," answered Bob.

"It made a picture on a screen. Something like TV," Helen explained.

"What did it look like?" asked Mr. Grant.

"Curves that danced around," answered Don.

"Mine was smoother," added Helen. "Mrs. Rosen said I held the pitch perfectly."

"I wish I could see that," said Mr. Grant.

"Mrs. Rosen said she would show it to parents on visiting night," said Don.

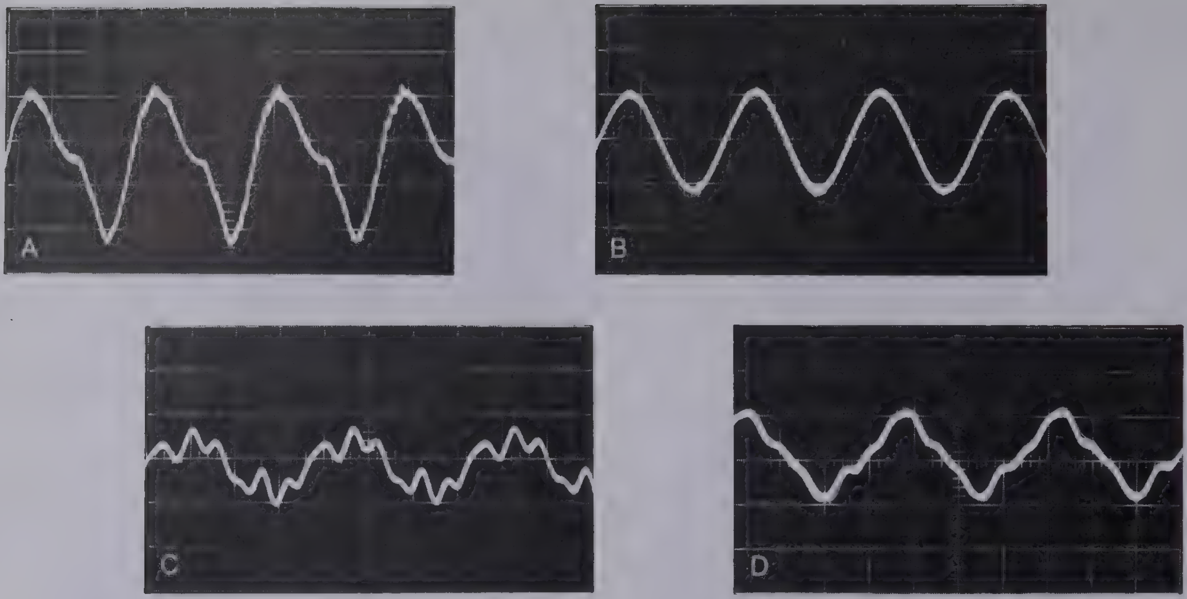


Figure 10-1 *How different sounds look on an oscilloscope: (A) Human voice sounding a single pitch. (B) Tuning fork, same pitch as human voice. (C) Clarinet, different pitch from human voice. (D) Trumpet, same pitch as clarinet.*

How Are Sounds Made?

10-1 Sounds have their pictures taken

Materials
oscilloscope, microphone, amplifier, tuning forks, musical instruments

★ Mrs. Rosen used an oscilloscope (ah-SIL-uh-skope) to show pictures of the sounds. You can see some of them in Figure 10-1. If possible, your teacher will let you do this too. You can sing or whistle. Try clapping your hands. If you have a musical instrument, bring it in. Use instruments that can hold a tone. For example, a guitar is not too good. The sound dies out too soon. A violin is better. Clarinets and trumpets are good. So is a harmonica. Use your imagination.

Notice that some sounds make nice smooth curves. Others make bumpy-looking ones. Some curves are quite complicated. In Figure 10-1, what do you notice when two sounds have the same pitch? If you have a mike to use, try to make a smooth-looking sound with your voice. Then try to make a bumpy one. ★

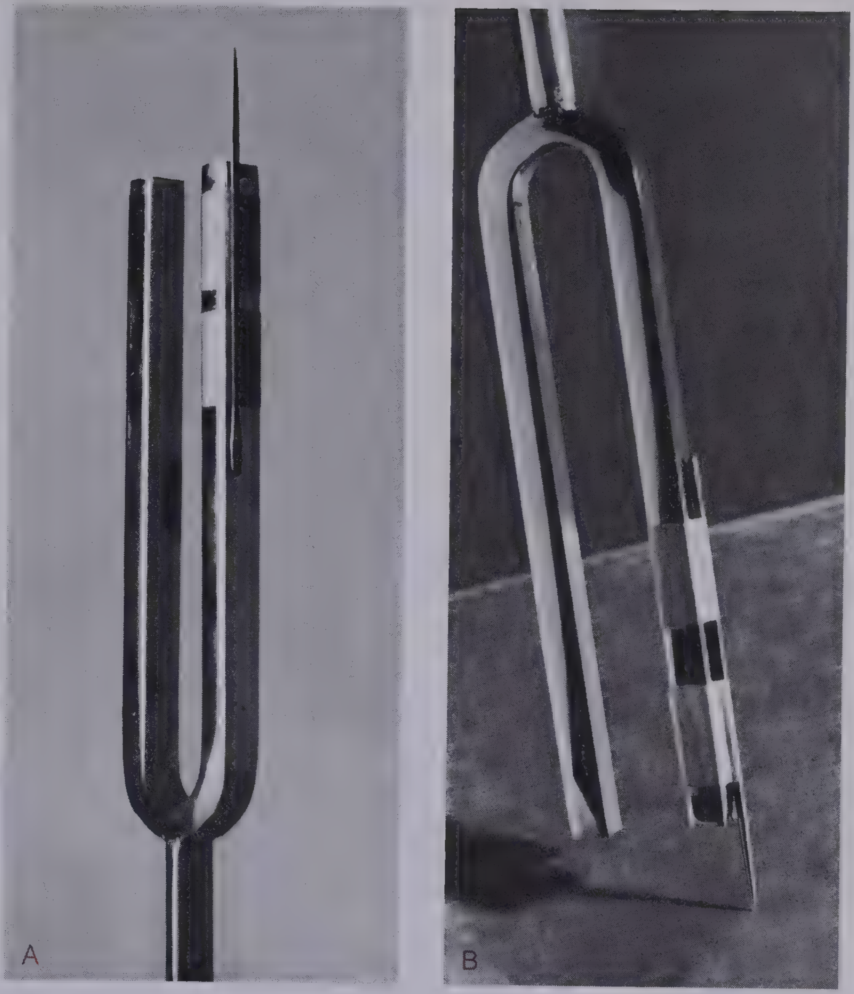


Figure 10-2 *(A) The needle tip should stick up about ½ inch. (B) Let the needle just barely scratch a line on the waxed paper.*

10-2 You can make sound pictures

Materials
tuning fork, tape, needle, waxed paper

★ Tape a needle to one prong of a tuning fork (Figure 10-2A). Sound the tuning fork by hitting it against the edge of a book. Immediately run the needle lightly over the waxed paper (Figure 10-2B). If you let the needle press down hard, the fork will stop. Then you will get only a straight line. But if you let the needle press down very lightly you will get a wiggly line. This is a picture of the sound, something like the ones made by the oscilloscope. Compare your picture with the ones in Figure 10-1 or with the ones you saw with the oscilloscope. How are they alike? How are they different? ★

Materials
tuning fork, water, trumpet or drum, paper, piano or guitar

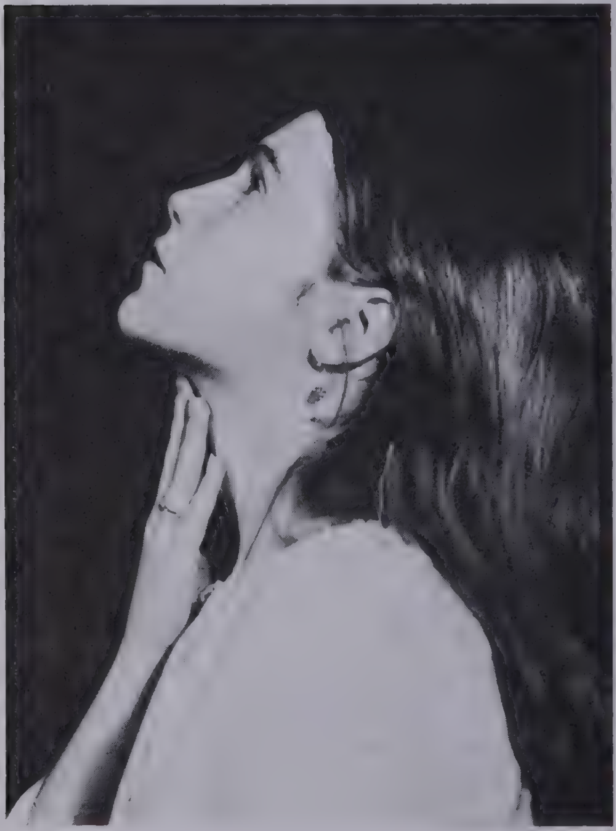
10-3 Vibration

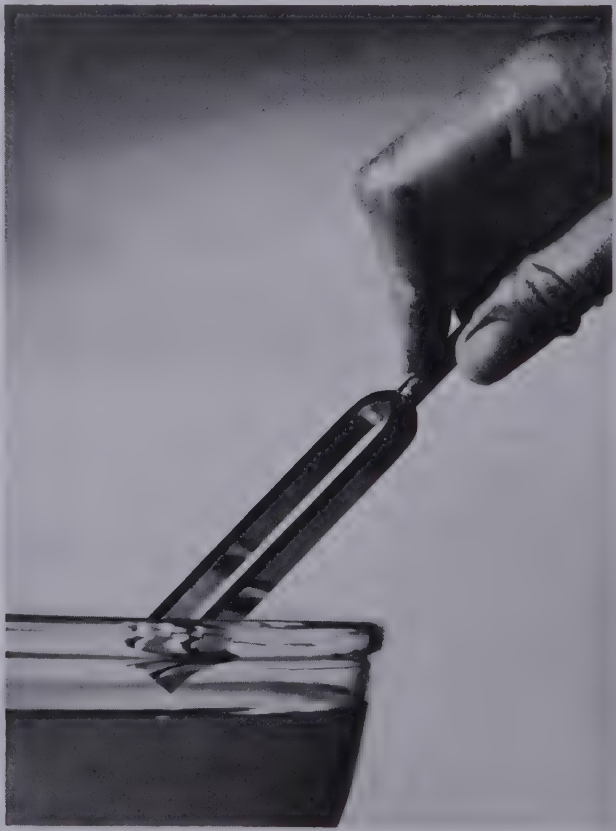
★ Feel your throat while you talk (Figure 10-3). You can feel it moving back and forth very quickly. This kind of motion is called **vibration** (vy-BRAY-shun). Sound your tuning fork. Can you see vibrations? Probably not. Hold the fork upside down. Bring it slowly down until the prongs touch the top of the water (Figure 10-4). What happens? Was the fork vibrating?

Feel the outside of a trumpet or drum while it is making a sound. Put a piece of paper on the strings of a piano or guitar. What happens when the instruments are sounding? All of these things are vibrating. Everything that makes a sound is vibrating. See if you can find other examples. ★

Figure 10-3 (*left*) *Find the place where you feel the most vibration. Which sounds can you feel best?*

Figure 10-4 (*right*) *Touch both prongs to the water at once.*





10-4 How does sound travel?

Sound gets to your ears through the air. Air is made of particles with lots of space in between them. To see how these particles can get the sound to you, try some experiments with a slinky.

Materials
slinky, tape

★ Stretch your slinky out about 15 or 20 feet on the floor or a long table (Figure 10-5). One person should hold it firmly at one end. A second person holds the other end. Be sure the slinky is not moving. Have the second person suddenly push his end in and back out. What do you see? The movement that travels down the slinky is called a **pulse.** Calm the spring down. Now have the pulse-maker push the spring in and out quickly three or four times. Notice that several pulses follow each other.

Fasten a piece of tape to one loop of the slinky. Send a pulse down the slinky and watch the tape. Notice that it moves back and forth, but does not really go anywhere. ★

Figure 10-6 shows several pulses traveling in a slinky. Notice that the loops are close together in some places and far apart in others. The "togetherness" travels down the slinky. But the loops bounce back and forth. They do not travel along the slinky.

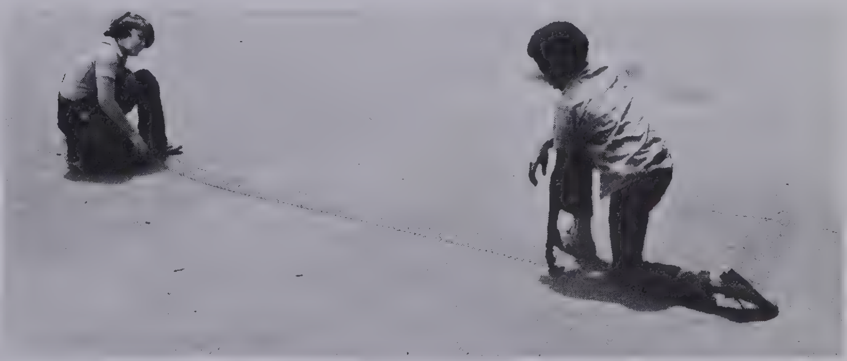
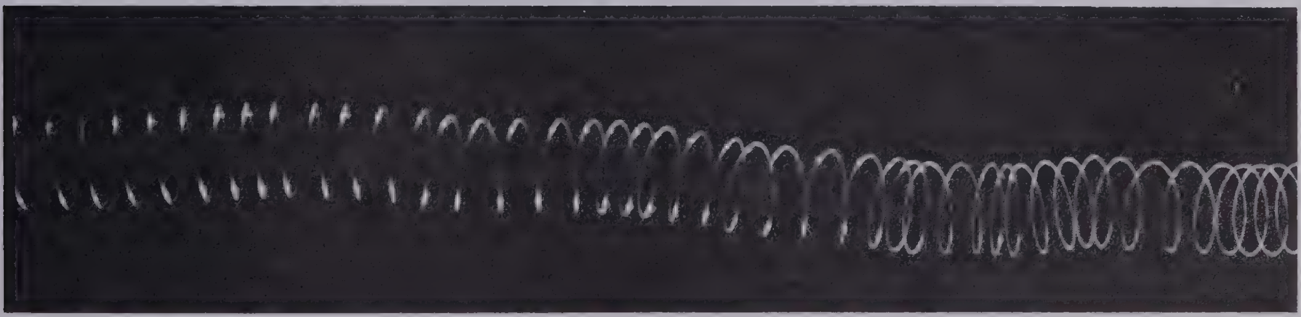


Figure 10-5 (*right*) *Hold one end of the slinky firmly in place.*

Figure 10-6 (*below*) *Do all the pulses travel down the slinky at the same speed?*



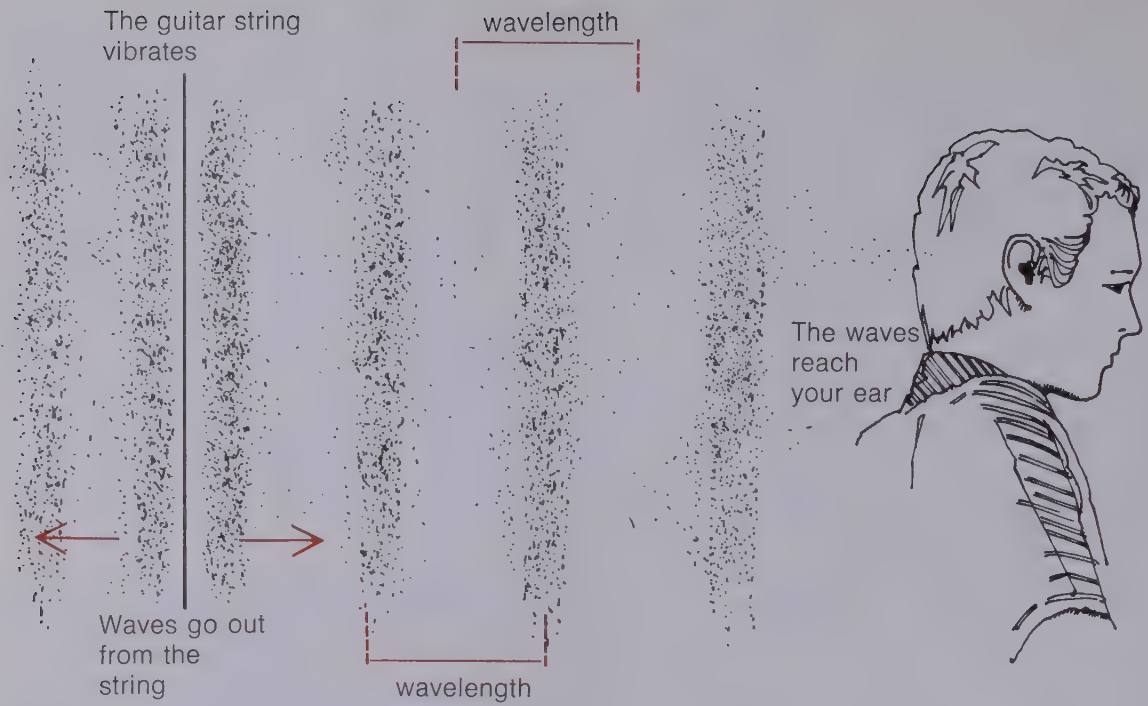


Figure 10-7 *The vibrating guitar string pushes air particles together, then spaces them out.*

The same sort of thing happens in the air when a guitar string vibrates. Study Figure 10-7 to see how this works. The vibrating string sends pulses through the air particles. A series of pulses like this is called a **wave,** a sound wave. The **wavelength** is the distance from one part of the wave to the next part that is just like it.

Pulses enter your ear. Down inside your ear is the eardrum. This is a thin piece of stretched skin. The pulses make the eardrum vibrate and you hear the sound.

Notice that the waves carry energy from one place to another. The guitar string has energy when it vibrates. It gives energy to air particles. The particles do not travel to your ear. They just pass the energy along from particle to particle until it reaches your ear.

The picture on the oscilloscope did not look like the picture of the sound wave in Figure 10-7. This is because the oscilloscope makes graphs of the waves. Whenever the particles in a wave are close together, the wave is high on the screen. When the particles are far apart, the wave is low.

If two sounds have the same pitch, they have the same wavelength. This is true no matter how fancy the shape of the wave may be. The wavelength of middle C is about 130 cm. Sounds have wavelengths from about 2 cm for the highest pitch you can hear to about 1700 cm for the lowest you can hear.

10-5 How fast does sound travel?

Materials
whistles, stopwatch, long tape

★ Borrow two whistles from the gym department. Borrow a stopwatch too. Go outdoors and measure out as long a distance as possible, at least 500 ft. Make it longer if possible. Have someone stand at one end of the measured distance with a whistle and stopwatch. Have another person with a whistle stand at the other end. The first person should blow his whistle and start the watch at the same time. When the second person hears the whistle, he blows his whistle. When the first one hears the second whistle, he stops the watch. From the distance and time you can find the speed of sound. Remember that the distance is twice the length you measured. ★

The speed of sound in air is usually more than 1100 ft/sec, more than 330 m/sec. It changes when the temperature changes. Figure 10-8 tells you the speed for different temperatures. Use it to see how good your measurement was.

Figure 10-8 *The speed of sound in air.*

Temperature		Speed of sound	
°C	°F	m/sec	ft/sec
0	32	331	1087
20	68	344	1129
100	212	386	1266

If you know a place where you can make echoes, you can find distances. For example, the girl in Figure 10-9

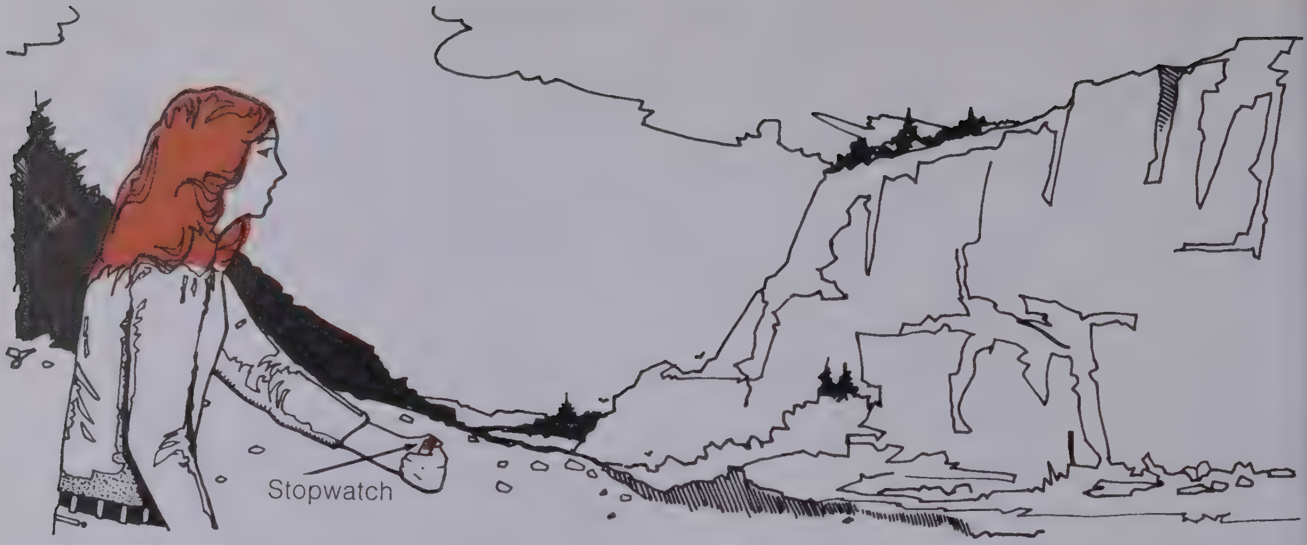


Figure 10-9 *You can estimate the distance to a cliff by using an echo.*

has just shouted. At the same time, she started her stopwatch. When she heard the echo from the cliff across the valley, she stopped her watch. The time was 3.0 sec. The sound had to travel to the cliff and back in that time. If the speed of sound was 340 m/sec, how far away was the cliff?

Sound waves can travel through water. They are used to tell the depth of the ocean. A sound wave is sent out and the time until the echo comes back is measured. The distance is found the same way you did it for the cliff. The equipment for sending out the sound wave and measuring the time is called **sonar.**

Sound waves travel through any material. They travel through liquids and solids faster than through air. In water they go about four times as fast as in air. In steel they go about 16 times as fast as in air. Sound waves cannot travel through a vacuum.

Did You Get the Point?

Vibrating sources send sound waves through particles. The sound waves make the particles vibrate. They do not travel along with the waves.

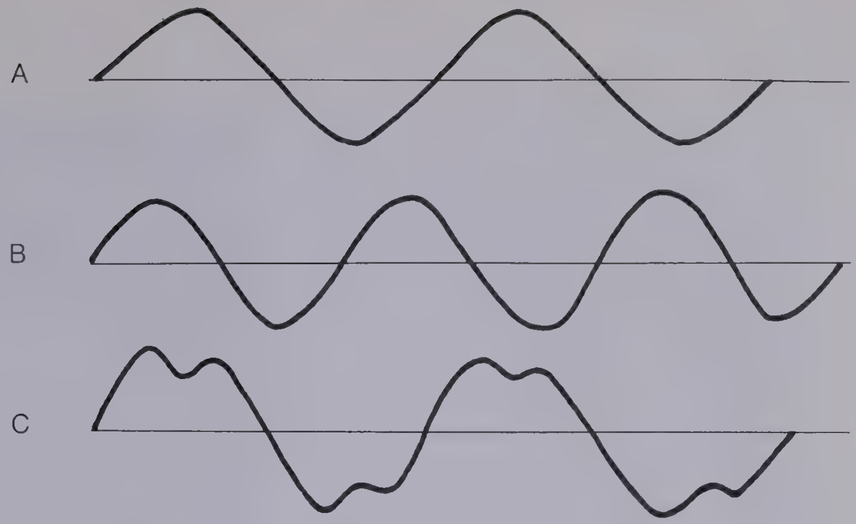


Figure 10-10 *Graphs of three sound waves for What Have You Learned?*

Sound waves carry energy from place to place.

Sounds of the same pitch have the same wavelength.

The speed of sound can be used to find distances.

What Have You Learned?

1. Which of the sound graphs in Figure 10-10 have the same pitch?

2. Which of the sound graphs in Figure 10-10 might have been made by a tuning fork?

3. In Figure 10-6, how many wavelengths long is the slinky?

4. If you do not have a stopwatch, you can count seconds by saying fast out loud, "This is one second, this is two seconds, . . ." Suppose you are watching a storm. You see a flash of lightning and start counting. When you have counted to three seconds, you hear the thunder. About how far away was the lightning?

5. In movies about Indians, you sometimes see one put his head to the ground to listen for approaching horsemen. Why does this work?

6. Explain why sound travels faster in warm air than in cold air.

7. Sonar is also used to locate fish or submarines. How might people know that it is not the bottom that is making the echo?

MUSICIAN

People who make music for a living pick up a lot of information about sound. Singers use the spaces in their bodies to change the sound of their voices. Instrumental musicians learn the movements that make pleasing sounds. All musicians know that different rooms change the sound of voices or instruments. They must learn to overcome this problem.

Most people who become professional musicians begin studying an instrument as children. After high school they continue music lessons with a private coach, in college, or in a conservatory of music. For a performer, practicing and studying music is a full time job.

Few musicians earn a lot of money by performing music. Most musicians teach music. A large number of people who have some music training choose occupations related to music. They may work in music publishing companies or recording companies. They may make or sell musical instruments. At radio and television stations, people with music backgrounds arrange musical programs and also pick background music for other programs.

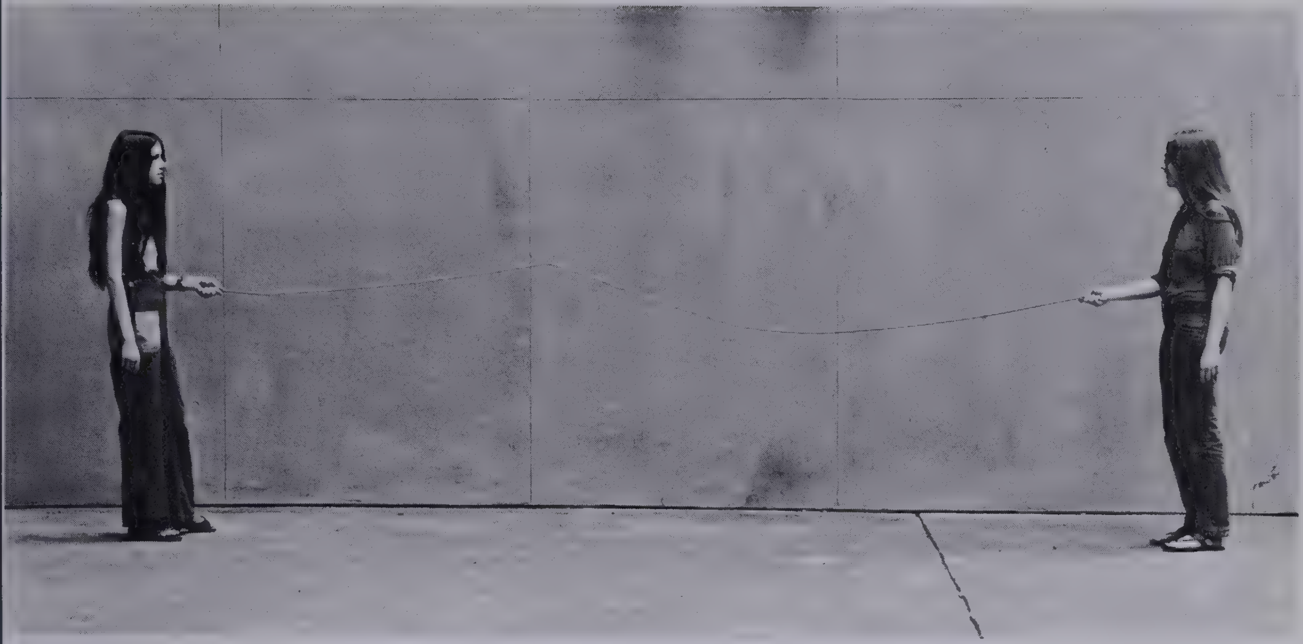


Figure 10-11 *Two students making waves.*

Waves

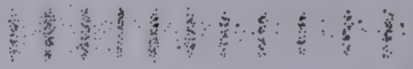
10-6 Some waves vibrate sideways

Materials
narrow spring, tape

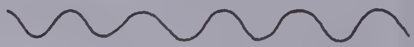
★ The students in Figure 10-11 are making a sideways pulse in a long spring. First they stretch the spring out a bit and hold it at the ends. That way it does not sag too much. Then one of them jerks her end quickly once up and once down. People in the class see a pulse rush down the spring. The people holding the spring see it too, but not as well. Try it yourself. Watch carefully to see what happens to the pulse when it gets to the other end.

Now make a lot of pulses by shaking the end of the spring up and down. Just one person should do this, not both. The other person holds his end steady. At first you will see waves going down the spring. Then they reflect from the other end. If the person who is doing the shaking keeps on, there will be much confusion as new waves meet reflected ones.

Fasten a piece of tape to one place on the spring. As a wave goes by, what does the tape do? How is this like the waves you studied with the slinky? How is it different? ★

Here is a sound wave: 

The wave travels this way →. The particles go → and ←. A wave like this is called a **longitudinal** wave.

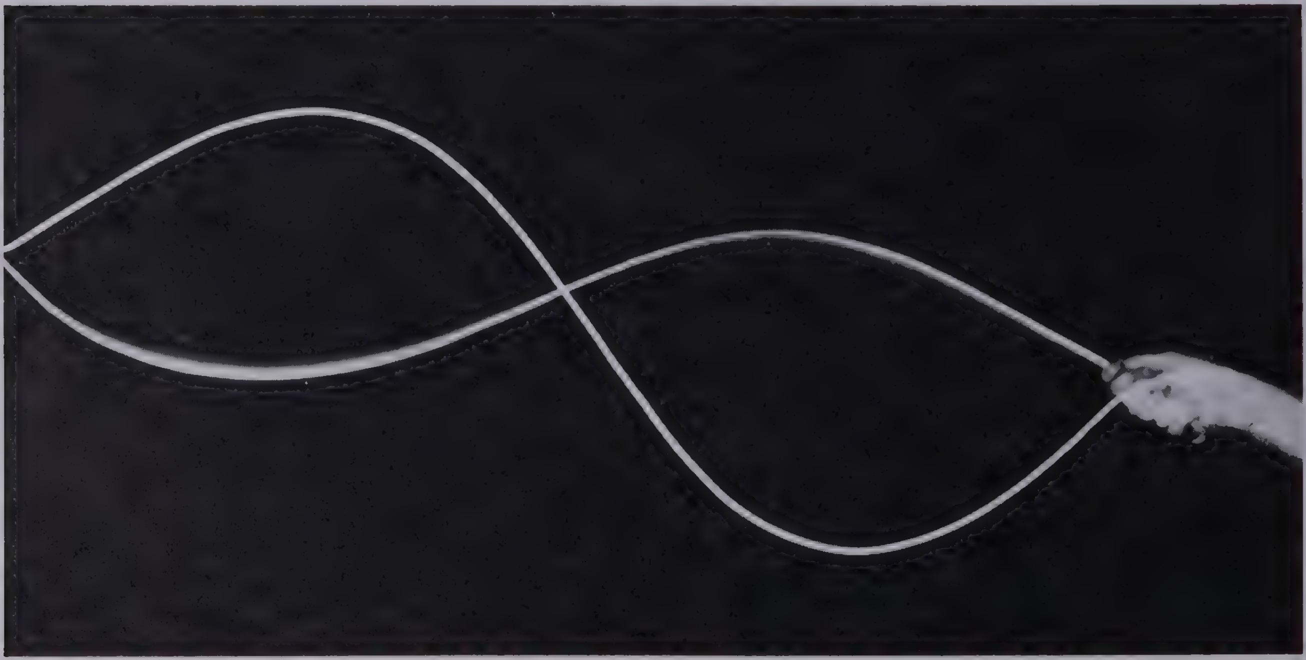
Here is a wave in a rope: 

The wave travels this way →. The parts of the rope go ↑ and ↓. A wave like this is called a **transverse** wave.

Materials
spring or clothesline

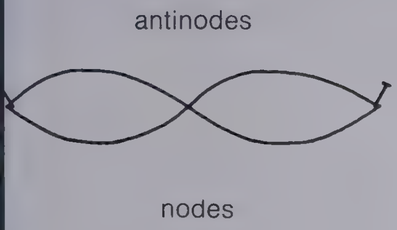
★ Now for some fun. Hold the spring again, as in Figure 10-11. Shake one end. Keep the other end steady. If you shake at the right speed, you can get it to look like Figure 10-12. The place in the middle stands still. In the wide places the spring swings madly up and down.

Figure 10-12 *Shake the spring at different speeds until you get a pattern like this.*



Shake a little faster and you can make three loops. Maybe you can make four by going faster still. See how many loops you can make. You can do this at home with a piece of heavy clothesline. It works with two people holding the rope or with one end tied to something.

Figure 10-13



This pattern is made when two waves pass each other going in opposite directions. If one wave tends to make the spring go up and the other one tends to make it go down, nothing happens at that spot. Places like this are called **nodes.** The places halfway in between are called **antinodes** (Figure 10-13). At the antinodes the two waves work together to make the spring go way up some of the time and way down some of the time. A wave pattern like this, with places that stand still, is called a **standing wave.**

aterials
linky

It is possible to get standing waves in a slinky too. If your slinky is on the floor, there may be too much friction. But if you have one that is suspended, see if you can make a standing wave.

Imagine that a sound is being made by a musical instrument. It is reflected from a wall. The wave going out from the instrument meets the reflection. Nodes and antinodes are formed. If you walked around the room, what would you hear if you walked into a node? What if you walked through an antinode?

10-7 There are standing waves in a guitar string

A guitar string vibrates with one antinode when you pluck it. But it can vibrate with two antinodes also, like the spring in Figure 10-12. Actually, it does both of these things at the same time. This is easy to prove.

aterials
uitar, chalk

Measure the length of the guitar string. Find the middle of the string. There will be a cross piece under the string at that point. Mark it with chalk.

Now pluck the string. Listen to the note. Then lightly touch the string at the exact center. This destroys the antinode there. The sound you were hearing disappears. But you did not destroy the antinodes for the two-piece vibration. Listen carefully. You will hear a note an octave higher. It was there all the time. You could not hear it before because it was too faint.

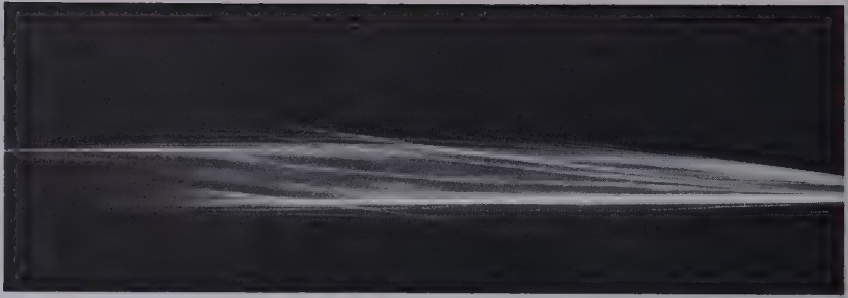


Figure 10-14 *This string is vibrating in several ways at once.*

The guitar string vibrates in one piece. At the same time it vibrates in two pieces, as you have just shown. How could you see whether it vibrates in three pieces? in four pieces? The class will have to be extremely quiet while you test this. ★

A guitar string does a complicated dance. Figure 10-14 is a photograph of a string doing several vibrations at once. Most musical instruments do this. That is why the oscilloscope pictures of them are usually complicated. That is what makes the tone sound rich and full.

10-8 Standing waves on water

Figure 10-15 shows water waves seen from above. At the center, a vibrating source is bouncing up and down. Circular waves travel out. In Figure 10-16 there are two sources. Each one sends out circular waves. The two sets of waves cross each other and make a standing wave. There are lines where the water is quiet. They are called **nodal lines.** In between are rough patches where the waves are high. These are **antinodal lines.**

Materials
tuning fork

★ Sound a tuning fork. Then hold it near your ear. Rotate it slowly. What do you hear? The tuning fork has two prongs sending out waves. The waves form nodes and antinodes. When you rotate the fork you rotate the nodes and antinodes. When a node goes by your ear, the sound fades out. When an antinode goes by you hear it. ★

10-9 Waves bend around corners

Figure 10-17 shows what happens when waves come to a wall with a hole in it. If the hole is narrow compared with the wavelength, the wave bends around the edges of the

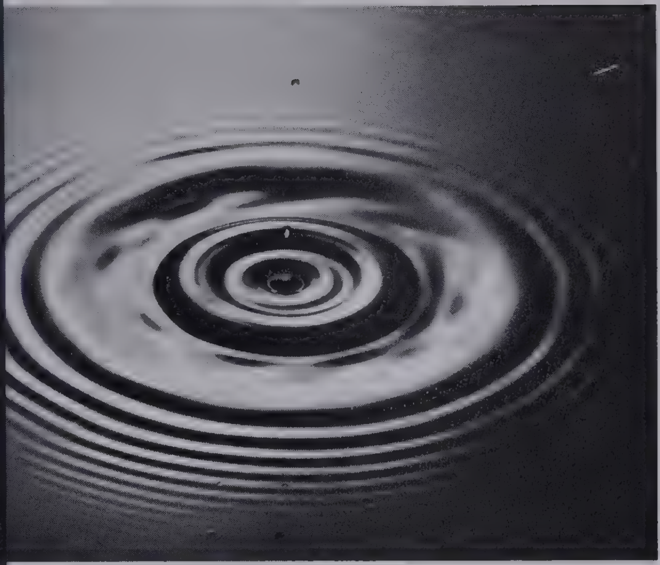


Figure 10-15 *A new wave forms each time an object dips into the water.*

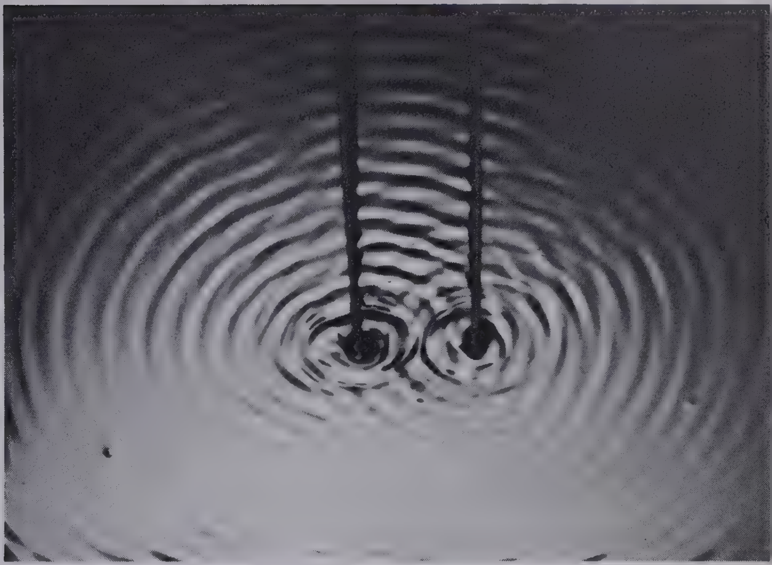
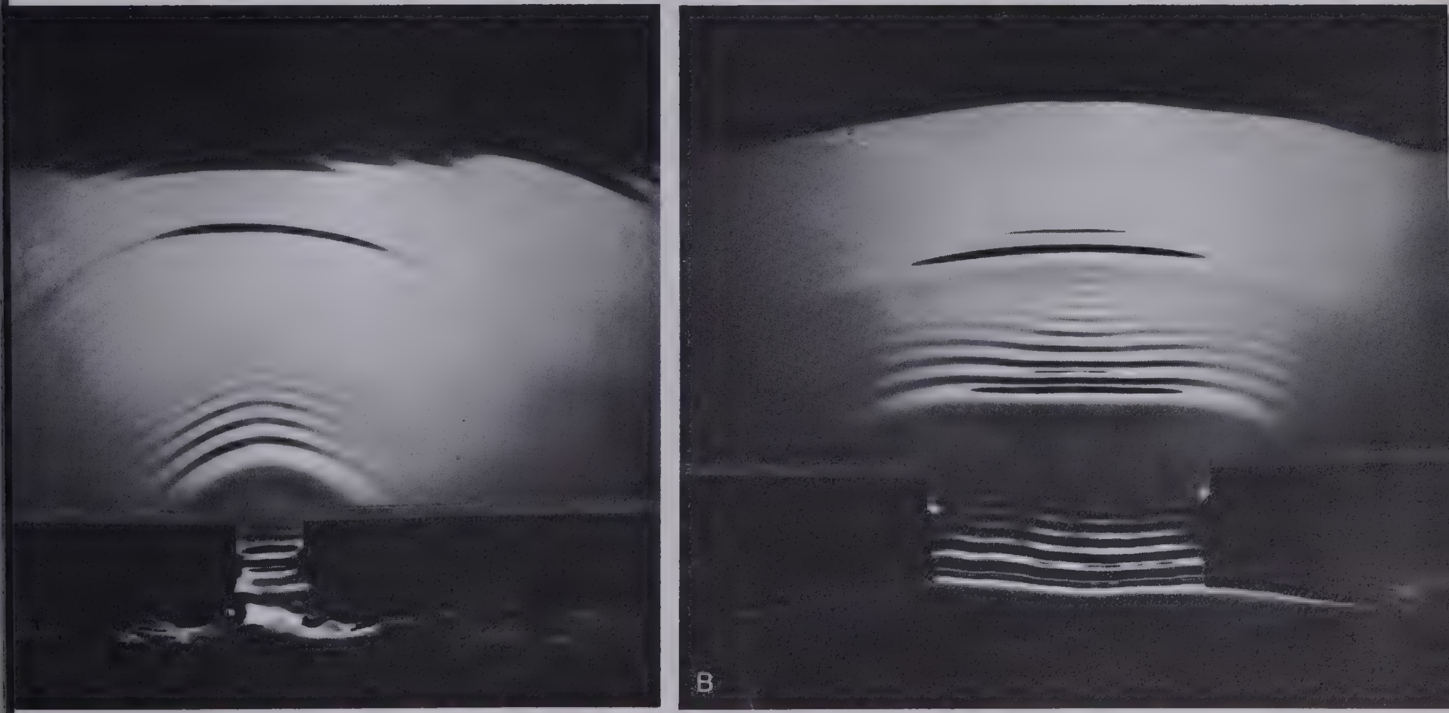


Figure 10-16 *Two objects dipping in the water make this pattern.*

Figure 10-17 *Which direction were the waves traveling?*



hole. It makes a circle on the other side. If the hole is wider, there is less bending.

Materials
pan, water, rod, blocks

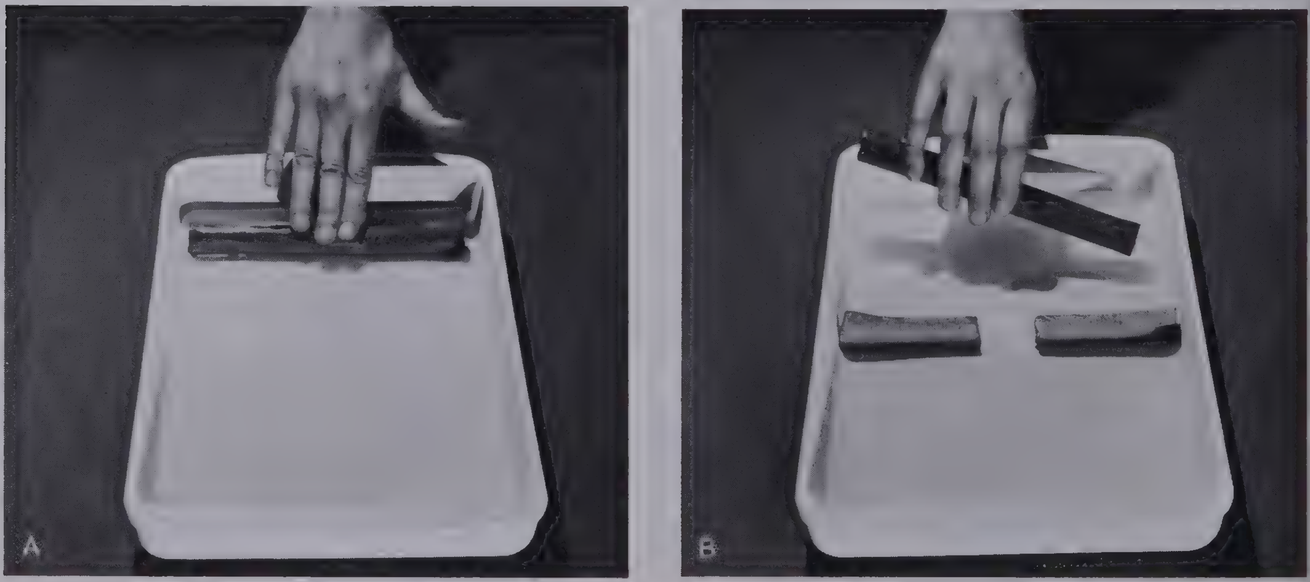
You can make waves like those in the picture. Put about $\frac{1}{2}$ cm of water in a shallow pan and take it near a window. Hold the rod as in Figure 10-18A and give it a little push. A pulse will go across the pan. You can see its shadow moving. Then put two blocks in the water as in Figure 10-18B. Make a pulse with the rod. What happens to the pulse when it goes through the hole?

Water waves are transverse. Sound waves are longitudinal, but they can bend too. Most sound waves you can hear are long enough to bend when they go through holes. This is why you can hear someone talking in another room. The sound waves bend around the doorway.

10-10 How to know a wave when you meet one

Waves carry energy from place to place. So do moving objects. Sometimes it is hard to tell whether energy is

Figure 10-18 *How to make waves bend. (A) Use a pan with a white bottom, or put a piece of white paper underneath a glass pan. (B) Use any kind of blocks, but be sure they do not float.*



carried by a wave or by a stream of particles. But only waves make nodes and antinodes. And only waves bend around corners without help. Particles turn corners if something pushes them. They do not do it without help.

Some waves vibrate sideways.

Some waves vibrate back and forth along the direction of travel.

Musical instruments can vibrate in more than one way at the same time. This makes them sound better.

Waves that cross each other can make nodes and antinodes.

Waves can bend around corners without help. This happens best when the waves are long compared with the size of the hole they go through.

1. What kind of wave does a snake make when it travels?

2. Toni's father is a helicopter pilot who watches traffic for a radio station. One day he took some pictures from the air. One of them looked like Figure 10-19. The cross marks are at the toll booths on a super-highway. When Toni saw the picture, she said, "That looks like a wave to me."

"What do you mean?" asked her father.

How would you explain it to him? What kind of wave was Toni thinking about? How is the picture different from a real wave?

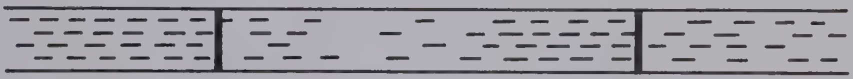


Figure 10-19 *For question 2 of What Have You Learned?*

3. A certain wave has a wavelength of less than 1 mm. How would it behave going through a door?

4. In Figure 10-20A, notice how the parts of the wave are named. In Figure 10-20B, 1 and 2 are two sources of waves. A crest from 1 reaches point 3 at the same time as a trough from 2. Is point 3 on a nodal line or an antinodal line?

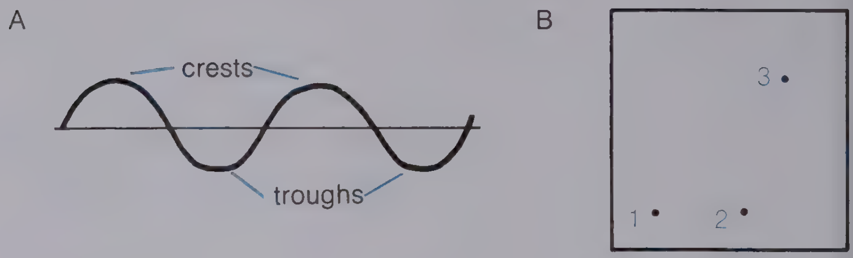


Figure 10-20 *For question 4 of What Have You Learned?*

SKULLDUGGERY

1. Number the lines on a sheet of paper from 1 to 21. In the paragraph below you will find that words have been left out. Each word has a number. Write the missing word on the line of your paper that has the same number. When you are done, the first letter of each word will make a sentence about sound.

(1) are made by sources that are (8). You can see a picture of (21) voice on an (2). The picture is really a (20) of the sound. The distance from one part of a wave to the next part that is exactly like it is the (6). If you shake a (14) up and (5), (15) can make (4) and antinodes in it. Pulses travel down the rope and (19) from the other (9). The parts of the rope vibrate (3) and down. This kind of wave is transverse. Sound waves and waves in a (10) are longitudinal. When you rotate a tuning fork near your (16), you hear the sound get loud and soft. The loud sound comes when an (12) goes by and the soft one when a (17) goes by. Sound waves travel more (13) in water than in air. Sonar tells how deep the water is by measuring the time for an (18) to come back. Waves can bend around (11). This is why you can hear people talking when they are in (7) room.

2. Suppose you go to a track meet and sit some distance from the starting line. Why might you see the runners start before you heard the gun? What would happen if the track meet were on the moon?

3. Design a new musical instrument and build it out of simple materials, like paper or string or bottles. Be able to play a scale or a simple tune for the class on your instrument.

FOR FURTHER READING

Berger, Melvin, and Frank Clark. *Science and Music: From Tom-Tom to Hi-Fi.* New York: McGraw-Hill, Inc., 1961. How musical sounds are produced. Explains modern tape recording and sound reproduction.

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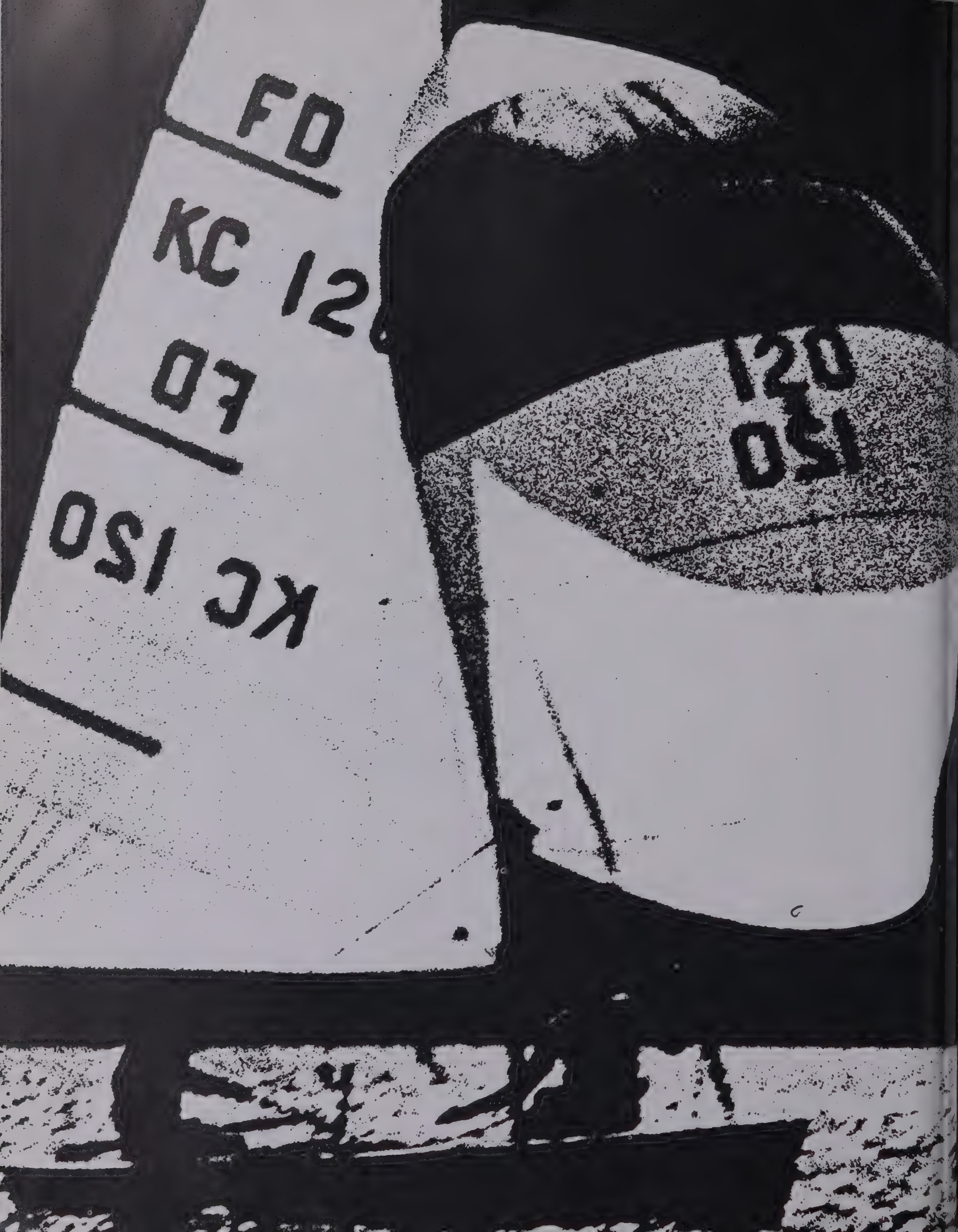
WHAT'S NEXT?

Did you ever try to look around a corner without putting your head around the corner too? Have you ever seen a ruler looking bent when it really wasn't bent? Did you ever make a picture with a lens? Did you ever notice that the inside of a neon tube looks empty? You will do some of these things when you read the next chapter.


FD
KC 120
120

Light

What makes a really eye-catching photograph?

First, the skill of the photographer in choosing the right thing to put on film—the best angle, the most striking mixture of light and shade, the most interesting balance of shapes and forms.

But this is only part of the story. The word ''photography'' is made up of two Greek words meaning ''picturing with light,'' and that is just what a photographer does with a camera and film. So a photographer must know something about the way that light behaves. How do the different lenses change the way light behaves? How much light is needed? How can the amount of light be controlled? These are only a few of the problems that a photographer has to think about before taking a picture.

Photography is a blend of art and science. It isn't easy to teach anyone the art, but the science is just a part of the science of light. You will be learning something about that in this chapter.

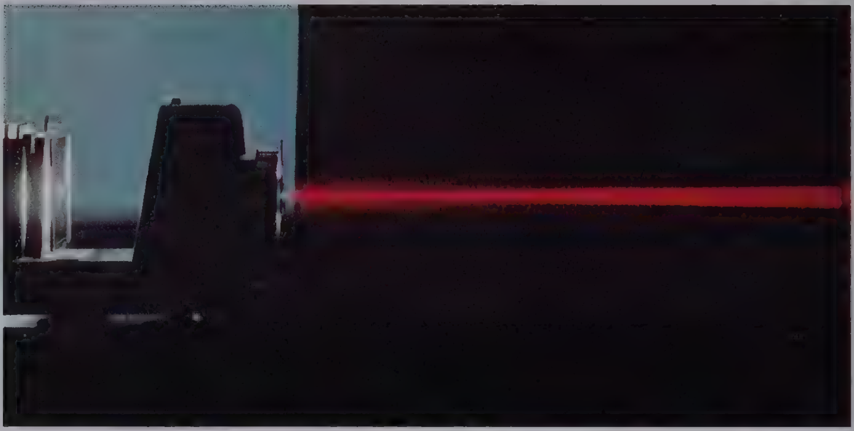


Figure 11-1 *Light from a slide projector goes in a straight line.*

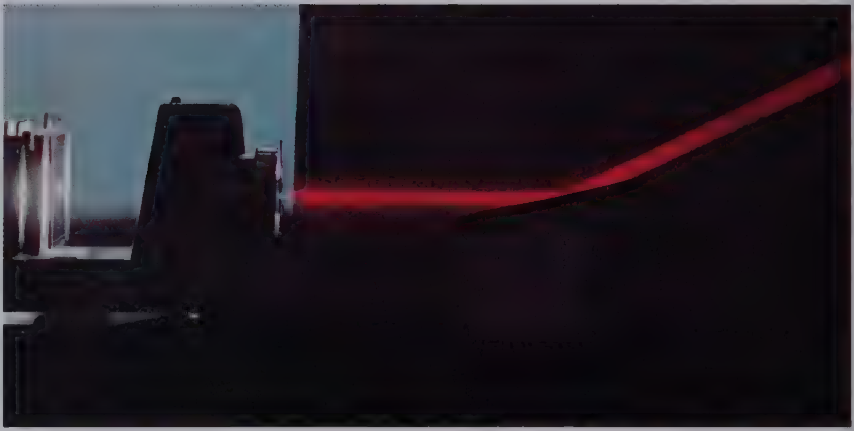


Figure 11-2 *A mirror changes the path of the light.*

The Path of Light

11-1 Light travels in straight lines unless . . .

Figure 11-1 shows light coming from a slide projector. Someone has made a lot of dust by beating two chalkboard erasers together. You can see where the light goes because of the dust. As you see, it goes in a straight path.

One way to change the direction of the light is to use a mirror as in Figure 11-2. The light is bounced off, or **reflected.** When the light is reflected, does it still go in a straight line, or does it curve?

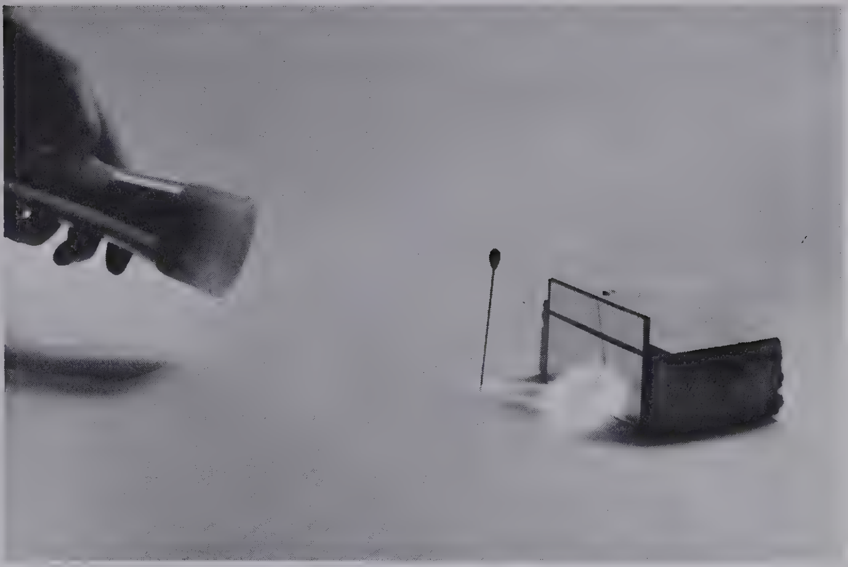


Figure 11-3 *Set up your equipment like this to see how light reflects from a flat mirror.*

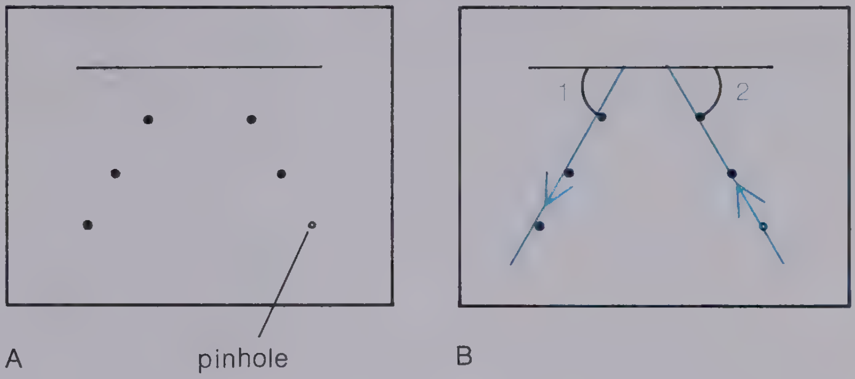


Figure 11-4 *Draw the dots and lines very carefully.*

11-2 How light is reflected from a flat mirror

Materials
flat mirror fastened to block, paper, cardboard, pin, ruler, protractor, flashlight

★ Set up your materials as shown in Figure 11-3. Draw a line along the edge of the mirror. Your partner should hold the flashlight so that you can see the shadow of the pin on the paper. You must also be able to see the reflected shadow. Probably the shadow gets a little wider farther from the pin, and wider still in the reflected part. Carefully put two dots in the center of the shadow on its way to the mirror. Put three dots in the center of the reflected shadow. Take away the mirror and pin. Your paper will look like Figure 11-4A.

Draw lines through the dots with a ruler, as shown in Figure 11-4B. Make arrowheads to show the direction the light was going. Use a protractor to measure angles 1 and 2.

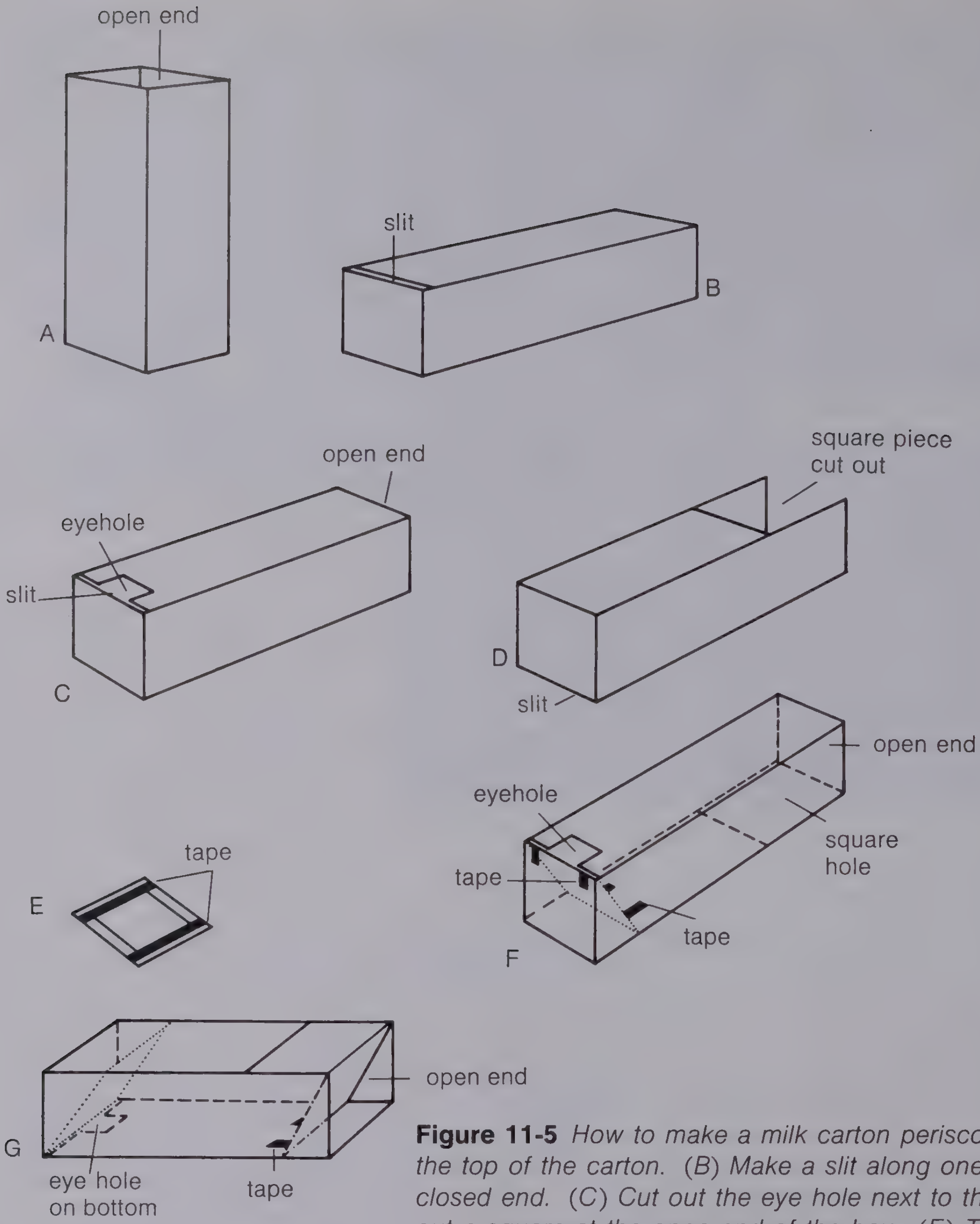


Figure 11-5 *How to make a milk carton periscope. (A) Cut off the top of the carton. (B) Make a slit along one edge of the closed end. (C) Cut out the eye hole next to the slit. (D) Cut out a square at the open end of the box. (E) Tape each mirror to the center of a piece of cardboard. Use cardboard big enough to fit into the carton as in the next picture. (F) Push the cardboard with the smaller mirror into the slit by the eye hole. Tape it in place. Trim the eye hole until you can see the mirror through it. (G) Tape the other mirror in place as shown, mirror up.*

Do this again, putting the pin in a new place or moving the flashlight so that the angles are different. Change places with your partner so he can make drawings too. Everyone in the class will have two drawings with the angles measured. Put the drawings in your notebook.

Compare angle 1 with angle 2 in each of your drawings. See what others in the class have for their angles. Make a rule about what happens when light is reflected from a flat mirror.

Do the incoming and outgoing rays touch each other in your drawing? How do you explain this?

11-3 You can make a periscope

Materials
quart milk carton, 2 mirrors, cardboard, scissors, tape

Get an empty quart milk carton at home. Cut the top as shown in Figure 11-5A, wash it clean, and bring it to class. If you can, bring an extra carton. You might make a mistake with the first one. Also bring small mirrors if there are any at home that can be spared. Even broken pieces can be used. If you cannot find them at home, your teacher will help you to get some.

Follow the directions in Figure 11-5. When you have finished your periscope, use it to look over someone's shoulder or around a corner.

After you have used your periscope, see if you can use the mirror rule to explain how it works.

11-4 Another way to see around a corner

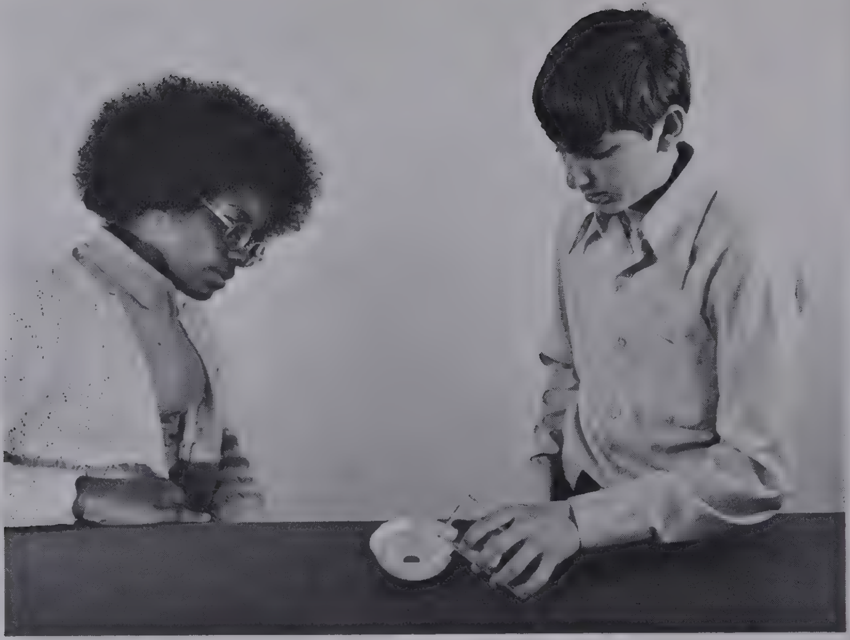
Materials
cup, penny, container of water

Put something small that will sink in water (like a penny) into an empty cup. Back away from the cup until you cannot see the penny (Figure 11-6). Don't move your head. Now let your partner pour water into the cup slowly. There should be no bubbles or ripples. What do you see? Change places and let your partner see too.

Materials
aquarium, milk, lamp

To see why this works, fill a flat-sided aquarium with water. Add a few drops of milk, just enough to make the water a little cloudy. Shine a strong, narrow beam of light into the water, as shown in Figure 11-7. You should be able to see the beam in the water. Maybe you can see it in the air too. If not, make a little chalk dust to show it. Is the path of the beam in the air straight? Is it straight

Figure 11-6 *Back up just enough so you cannot see the penny.*



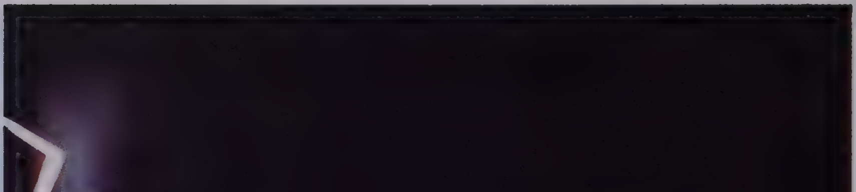


Figure 11-7

in the water? What happens when it goes from air into water? What happens if it comes out on the other side? Make a drawing to show the answers to these questions. Change the angle of the beam. Try both of the positions shown in Figure 11-8. Make drawings to show what happens.

Use your first drawing to explain why you could see the coin only when there was water in the cup. ★

Light bends when it goes from water to air or from air to water. Its path is straight in the air and in the water. The bending happens at the edge. Light bends, too, when it goes from air into glass. The bending of light when it goes from one material to another is called **refraction.**

When a fish looks down, things look all right. But when he looks up, his view is strange (Figure 11-9). He thinks

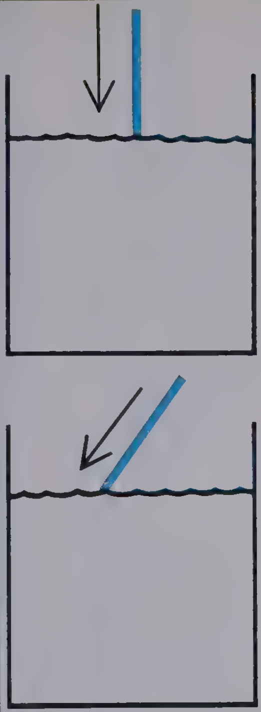
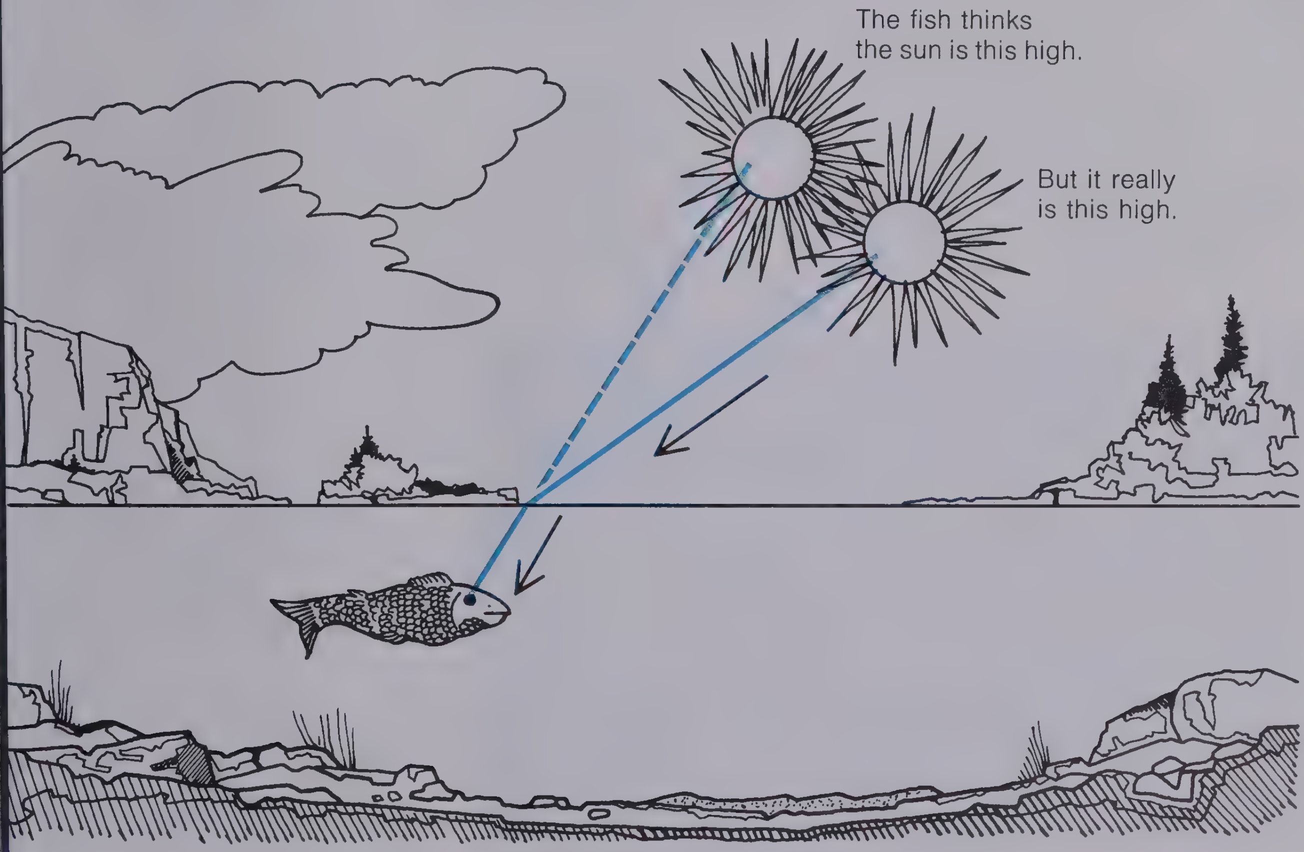


Figure 11-8 *What path does the light take when you do it this way?*

Figure 11-9 *A fish's eye view of the sun.*

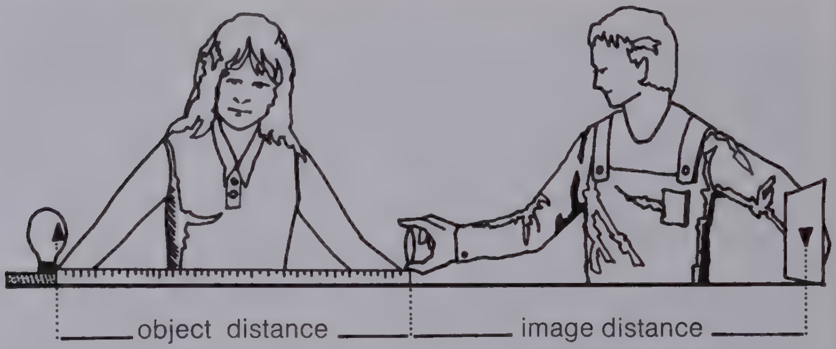

The fish thinks the sun is this high.
But it really is this high.

the sun is higher than it really is. You can test this when you go swimming. Lie on your back in the water. Notice how high a tree is beside the pond (or a light, if you are swimming in a pool). Then sink down under the water, still on your back. Open your eyes. Where does the treetop or the light seem to be now? It will look higher. Of course, if the top of the water is rough, things may only be a blur. But you can still get an idea of where they seem to be.

11-5 Fun with lenses

Figure 11-10 shows some students experimenting with a lens. One person holds the lens and a piece of paper for a screen. He places the screen where the lens makes a clear picture of the light. The picture is called an **image.** His partner measures how far it is from the light to the lens. Next she will see how far the screen is from the lens. The distance from the lens to the light (or to whatever she makes a picture of) is called the **object distance.** The distance from the lens to the screen is called the **image distance.**

Figure 11-10



Materials
lens, light, meter stick

Experiment with your lens. Do not move the light. Change the object distance by moving the lens. Then move the screen until the image is clear. When the image is clear, it is in focus. Record the object and image distances in a table like the one in Figure 11-11. Get the distance to the nearest half centimeter.

Figure 11-11

Object distance (cm)	Image distance (cm)	Size of image	Position of image
?	?	?	?

If the image is larger than the object, write "larger" in the *size* column. Or write "smaller" or "same" if that is how it looks. In the *position* column, tell whether the image is right side up or upside down.

Use at least three different object distances. After that, use the most distant object you can find. This will be outside the window. To make an image of something outside, have the lights out and all the shades pulled down except one. That one should be open only about 20 cm. Get on the side of the room away from the window with your lens and screen. You will not be able to tell the object distance exactly. Just write something like "across the street" or "two blocks away" for the object distance. The image distance for a very far-away object is called the **focal length** of the lens.

If the object distance is smaller than the focal length, it is impossible to make an image on the screen. However, you can still see images by looking through the lens. Hold your lens a little closer to this page than its focal length. How do the letters look?

11-6 Why do lenses make images?

Materials
flashlight, lens, chalk dust

How does a lens make an image? Figure 11-12 will give you an idea. You can do this yourself with a flashlight, a lens, and some chalk dust.

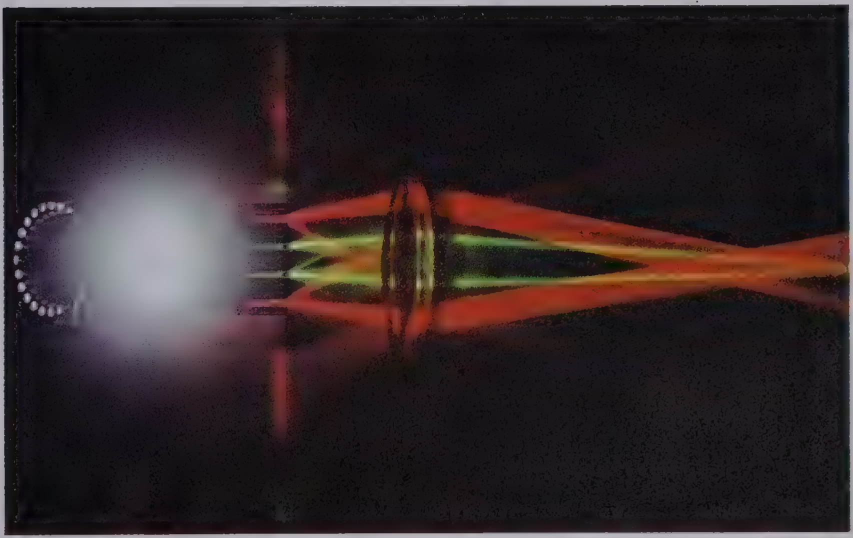


Figure 11-12 *This lens brings the light rays together.*

Figure 11-13 shows what is happening. Rays of light go out from the source in many directions. When a ray hits the glass, it is refracted. When it leaves the glass, it is refracted again. The diagram shows two of these rays. The lens bends the rays and brings them back together again. This is called **focusing** the rays. Light from each point on the source is focused at a different place on the screen. This makes the image (Figure 11-14).

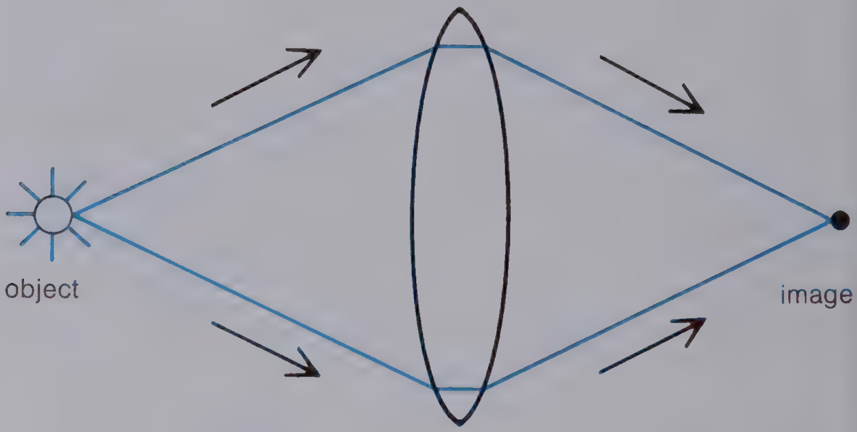
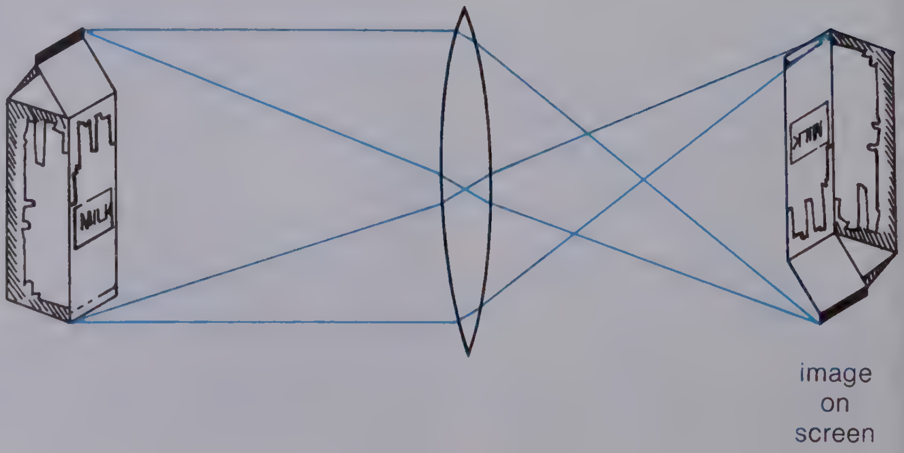


Figure 11-13 *Light rays bend when they go into the lens. They bend again when they leave.*

Figure 11-14 *If the screen is the right distance from the lens, the image will be focused.*



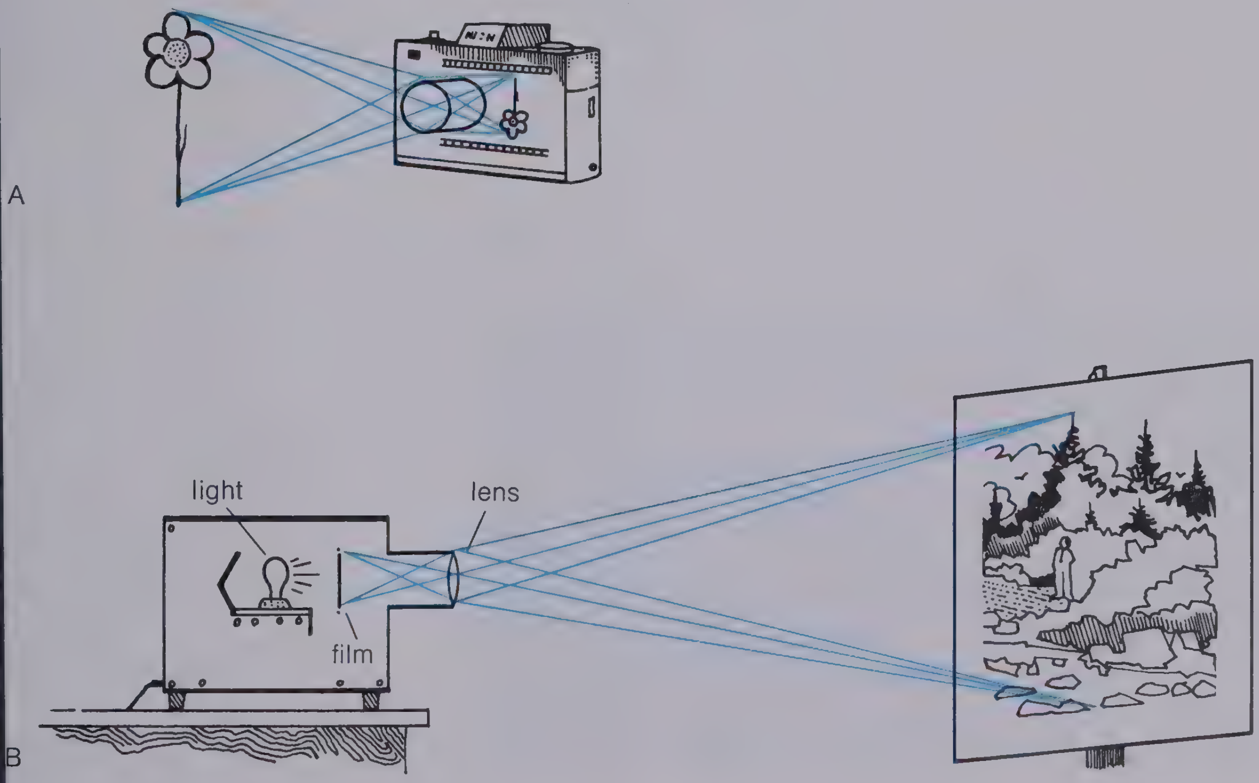
11-7 Rules for lenses

From your observations you can find rules to describe how the lens behaves. Read the questions below. Then discuss them with your class. If you think you know an answer, say what it is. See if others in your class agree. If everyone agrees that the rule works, write it in your notebook.

1. Is the image right side up or upside down? Is it always the same, or does it change?
2. What happens to the size of the image when the object distance gets smaller?
3. Is the image always smaller than the object, always larger, or sometimes smaller and sometimes larger?

Figure 11-15 shows some ways that lenses are used.

Figure 11-15 (*A*) *The lens of a camera usually makes a small picture of a big object. The object distance is larger than the image distance.*
(*B*) *A movie projector makes a big image from a small piece of film. The image distance is larger than the object distance.*



All of the lenses you used are thicker in the middle than at the edge. Some lenses are thinner in the middle (Figure 11-16). If you wear glasses, look at the lenses. What kind are they?

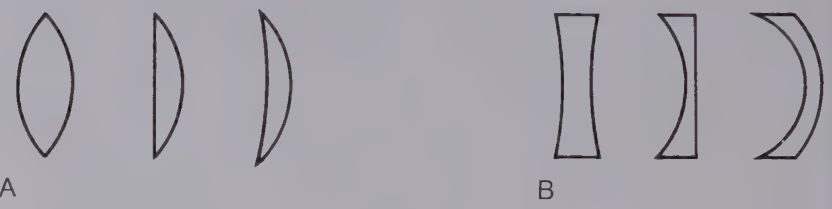


Figure 11-16 (*A*) *Lenses that are thickest in the middle are used by people who don't see nearby things well. These lenses are also found in magnifying glasses and projectors.* (*B*) *All these lenses are thicker at the edge than at the middle. People who wear glasses to see faraway things clearly need to use lenses like these.*

11-8 Your eye is like a camera

Figure 11-17 is a diagram of an eye. The part of your eye that bulges out in front is called the cornea. It helps to bend the light. Inside that there is a lens, which bends it some more and makes an image on the retina. The retina is like the film in a camera. Notice that the image inside your eye is really upside down. In the retina are many nerve endings that are sensitive to light. When light strikes them, they send a message to the brain. Your brain understands the message and turns the picture right side up.

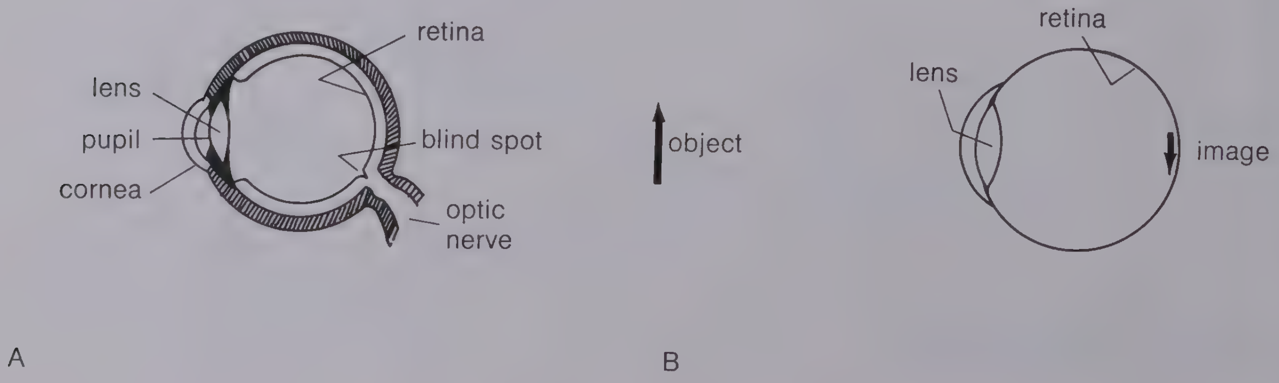


Figure 11-17 *In a mirror you can see only part of your eye. From the side, a human eye is shaped like a ball.* (*A*) *Important parts of the eye.* (*B*) *Path of light going toward the retina.*

The nerves from the retina are collected together to make the optic nerve. Where the optic nerve leaves the eye there are no endings. Therefore you are blind in that spot. You can prove this for yourself. Hold this book up at a comfortable reading distance. Close your left eye and look at the X that is printed on the next line.

X O

Keep looking straight at the X, but watch the O out of the corner of your eye. Bring the book slowly closer to your face. Suddenly the O will disappear. Bring the book closer. The O suddenly appears again. When you could not see it, its image was on the optic nerve.

Light usually travels in straight lines.

The direction of a ray of light can be changed by reflection.

The direction can also be changed when light goes from one material to another. This is called refraction.

Lenses refract light to make images.

1. Why is a periscope useful on a submarine?

2. Why does the straw look like this in the water (Figure 11-18)?

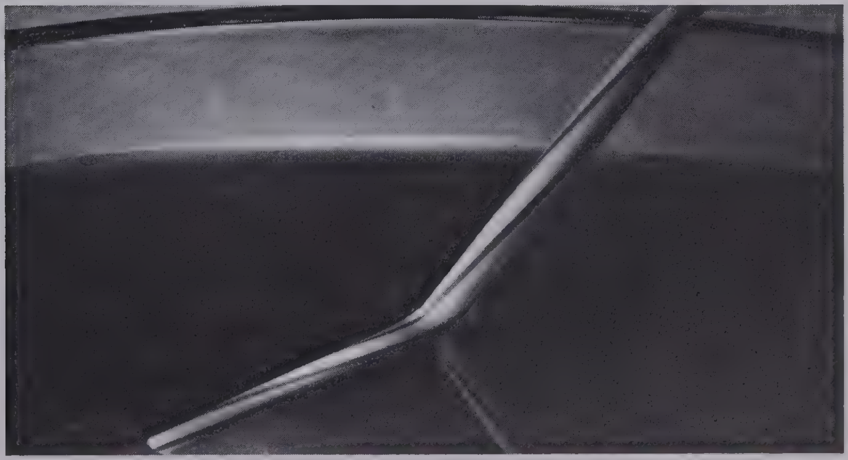


Figure 11-18 *For What Have You Learned?*

3. How should a slide be placed in a projector so that the image on the screen will be right side up?

Light and Color

11-9 White light is made of many colors

Materials
spectroscope, lights

★ Use your spectroscope (SPEK-truh-skope) (Figure 11-19) to look at light from an ordinary light bulb. You will see something that looks like Figure 11-20. The colored strips should be to the right and left of the center. If they are not, turn the end of the spectroscope near your eye to make them line up.

A **spectroscope** is something that separates out the colors that come from a light source. The yellowish-white light from a light bulb has all the colors of the rainbow. A strip of color made by the spectroscope is called a **spectrum** (plural, spectra). How many colors can you find in the spectrum of light from the bulb? The electric light gives off all the colors that the human eye can see. However, some of the colors are brighter than others. Which ones seem brightest?

The spectrum of light from the electric light is called a **continuous spectrum** because all of the colors are there. Nothing is left out. Figure 11-21 shows the spectrum from a mercury arc lamp. Lamps like this are often used for street lights. They give off a blue light. Notice that there are only a few colors in this spectrum. A spectrum like this is called a **bright line spectrum.** The mercury spectrum has a violet line, a blue one, a yellow-green, and two yellow lines close together. There is no red.

You will find several different light sources in your room. Look at each one with your spectroscope. Be sure you look at just one at a time. Do not stand where you can see two of them at once. In your notebook write the name of each source. After the name write whether it gives a continuous or bright line spectrum. If it has bright lines, write down their colors. If it is continuous, tell whether some colors are brighter than others.

Figure 11-19 *One kind of spectroscope.*

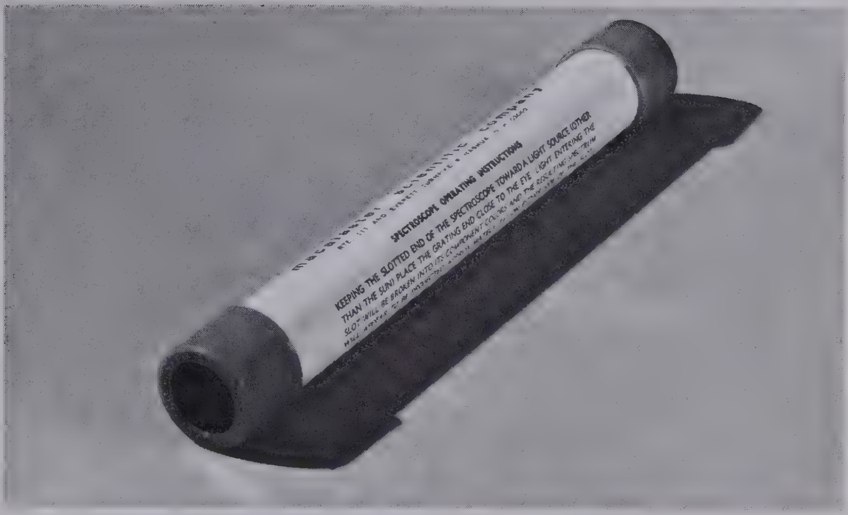

SPECTROSCOPE OPERATING INSTRUCTIONS
KEEPING THE SLOTTED END OF THE SPECTROSCOPE TOWARD A LIGHT SOURCE (OTHER
THAN THE SUN) PLACE THE GRATING END CLOSE TO THE EYE. LIGHT ENTERING THE

Figure 11-20 *When you use your spectroscope to look at an ordinary light bulb, you should see two spectra like this one.*

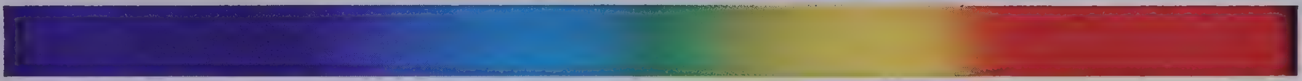
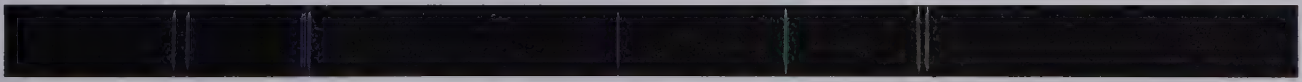


Figure 11-21 *A mercury arc street light made this spectrum. Can you use it to tell if there are mercury arc street lights in your town?*



When you have finished with the lights in the room, see what daylight is like. **Caution: Never look at the sun.** It can hurt your eyes. Let sunlight fall on a piece of white paper and look at the paper with your spectroscope. Or look at a white cloud. Sunlight shining on the cloud makes it look white. ★

11-10 Every source has a special spectrum

No two lights you looked at had exactly the same spectrum. Here are some facts about spectra: *Continuous spectra* are made by light from glowing solids, glowing liquids, and glowing gases under high pressure. *Bright line spectra* are made by light from glowing gases at medium or low pressure.

Which kind of spectrum did you find in sunlight? What does this tell you about the sun?

Our sun is a star. Most stars have spectra like the sun's. A few have bright line spectra. What can you tell about these stars?

Go over your notes about the spectra of different lights. What can you tell about each source from its spectrum?

Every gas has a different bright line spectrum. Later, in Chapter 15, you will learn how chemists use spectra to tell what something is made of.

11-11 What is light?

Light from the sun brings energy to the earth. When the light reaches the earth, the energy warms things up. And it helps plants to make food. The food stores energy. What is light, and how does it bring the energy?

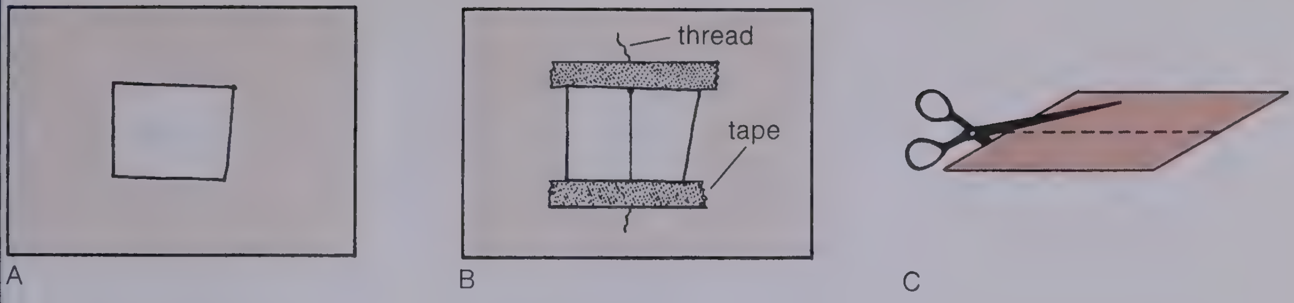
Some scientists have thought that light is a wave. Waves, you remember, are good at carrying energy from place to place. But other scientists said, ''If it is a wave, why doesn't it bend around corners like water and sound waves?'' These scientists thought that light is a stream of very tiny particles. Particles in motion carry energy too.

People who thought light might be a wave remembered that long waves bend better than short ones when they go through holes. Maybe light does not seem to bend because the wavelength is very short. They started looking at light through very small slits. They thought that if they had slits that were small enough, light might bend.

Materials
slits, lamp

You can try an experiment like this. First make the slits. See Figure 11-22 for directions. Hold the slits close to your eye with the slits up and down. Look at the lamp in front of the room. You will see light from the bright wire spread out. You will also see dark bands and then bright lines on each side of the center, something like Figure 11-23.

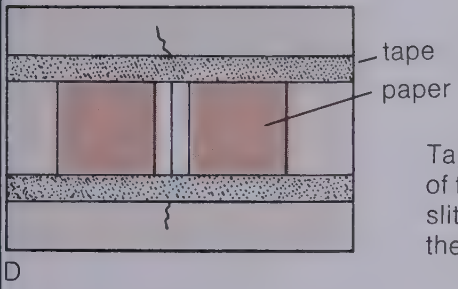
To understand what is happening, look back at Figure 10-16. There you see waves from two sources crossing each other and making nodes and antinodes. Something



Get a piece of thin cardboard about 5 cm on a side. Cut a hole in it. The hole does not have to be done carefully.

Tape a piece of sewing thread tightly across the hole.

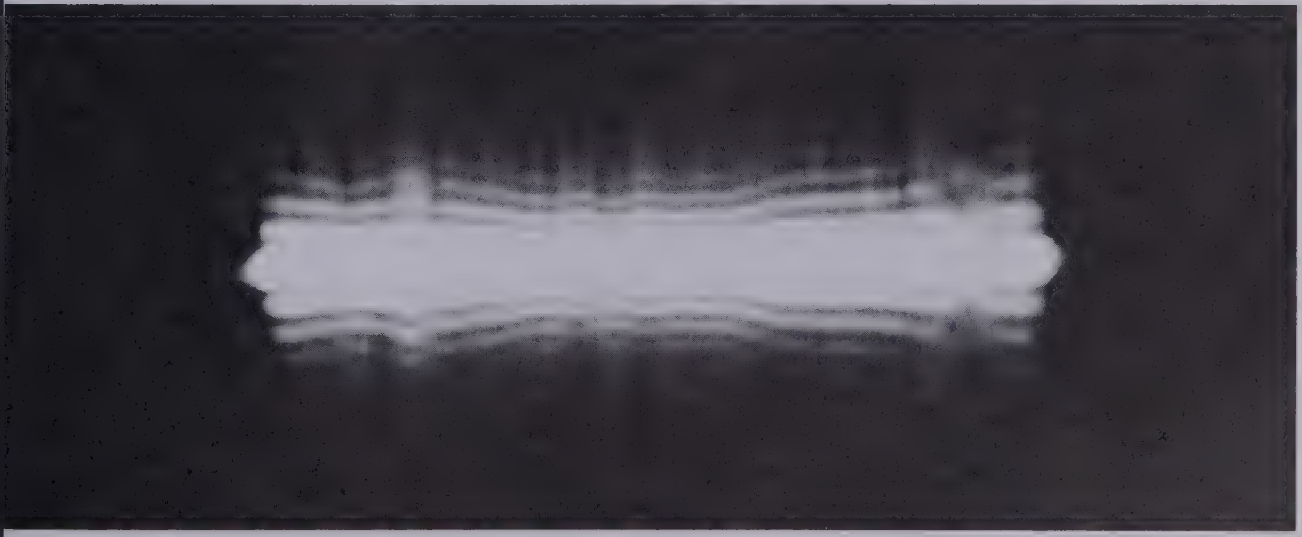
Get a piece of ordinary paper that is a little bigger than the hole. Cut it in two along a straight line.



Tape the two pieces of paper, one each side of the thread. This makes two very narrow slits. The narrower you make the slits, the better it will work.

Figure 11-22 *How to make slits for looking at light.*

Figure 11-23 *Light from a light bulb made this pattern when it went through narrow slits like the ones you made.*



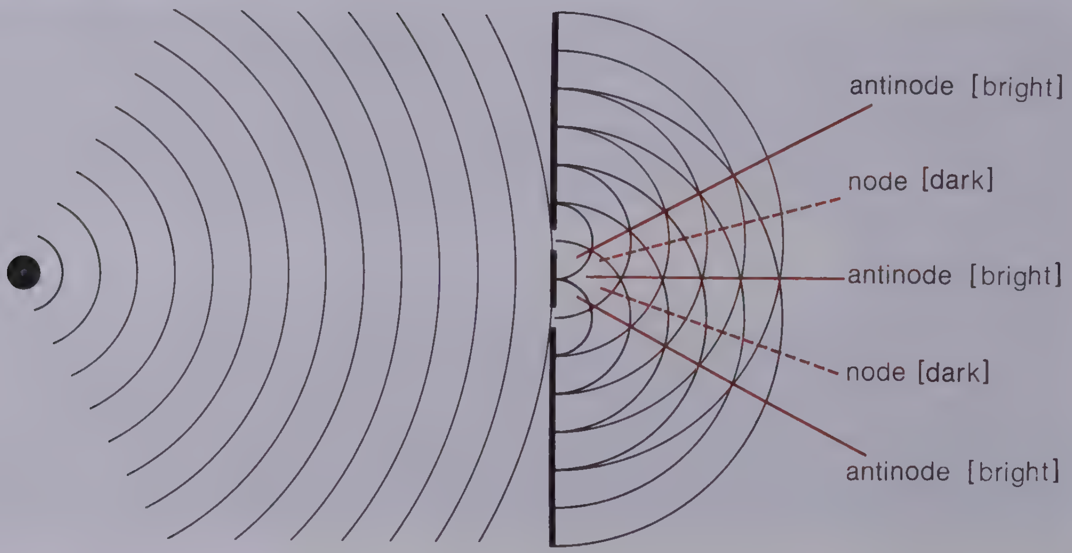
very much like this is happening with the slits. Light from the lamp goes out in waves as shown in Figure 11-24. When a wave crest reaches the two slits, it goes through and bends around the edges. This makes circular waves going out from each slit. They cross each other, just as the water waves did in Figure 10-16. So they make nodal lines and antinodal lines. Into your eye go the waves, making nodal lines and antinodal lines inside your eye. Everywhere an antinodal line touches your retina, there is light. Where a nodal line touches, there is darkness.

If the slits are very close together, you may see colors, not just bright and dark places. This is because each color has a different wavelength. Therefore, the nodal lines are in different places for each color.

By measuring how much the light spreads when it goes through narrow slits, scientists have found the wavelength. It is very small. More than a million light waves will fit into a space one meter long.

Light makes nodes and antinodes. Therefore, it must be a wave. This was discovered more than a hundred years ago. However, scientists discovered later that light sometimes acts as if it is made of particles. It is hard to imagine something that sometimes acts like a wave and sometimes acts like particles. But that seems to be how it is.

Figure 11-24 *Beyond the slit the waves from the two slits cross each other. This makes nodal lines and antinodal lines.*



Did You Get the Point?

White light is made of many colors.

A spectroscope separates the colors.

The spectrum of a light can tell a lot about the light source.

Light often acts like a wave.

What Have You Learned?

1. If you look at something blue or green in sunlight and then in ordinary electric light, the color may look different. Why?

2. The colors of light can be separated when the light shines through the edge of a piece of glass or other transparent material. See if you can find examples of this.

3. At night look at a distant light through the cloth of an umbrella or some other thin, woven cloth. Do you see colors? How do you explain this?

SKULLDUGGERY

1. Number the lines on a sheet of paper from 1 to 28. Write each missing word in the paragraph below on the line with the correct number. The dashes in the paragraph tell how many letters are in the word. Circle the letter that has a circle in the paragraph. The letters in the circles tell something important about light.

When light is (15) _ _ _ _ _ _ _ _ ○ from a flat (19) ○ _ _ _ _ _ the angles are equal. You made a (3) _ _ _ ○ _ _ _ _ _ to see around (27) _ _ ○ _ _ _ _. Light bends when it goes from air into water. This is called (18) _ _ ○ _ _ _ _ _ _ _. A (5) _ ○ _ _ uses the bending of light to make images. You moved the screen back and forth near the lens to get the (8) _ _ _ ○ _ in (23) _ _ ○ _ _. The image was upside (26) _ ○ _ _. Images are sometimes smaller than the (17) ○ _ _ _ _ _, and sometimes (14) _ ○ _ _ _ _. When the object is far away, the distance to the image is called the (6) _ _ _ _ ○ length. A (13) _ _ ○ _ _ _ makes images on film. Your (22) _ ○ _ is like a camera. Its lens makes images on the (7) _ _ _ ○ _ _. Then the (11) _ _ _ ○ _ nerve carries the message to your brain. A (24) _ _ _ _ _ _ _ _ _ ○ _ _ separates the colors of a light into a (10) _ _ _ _ ○ _ _ _. If the spectrum has all the colors of the (20) _ O _ _ _ _ _, it is called a (4) _ _ _ O _ _ _ _ _ _ spectrum. If the light source is a glowing gas at (25) O _ _ pressure, the spectrum is made of (9) _ _ _ _ O _ lines. The mercury spectrum has many (12) _ _ _ _ _ O, but the color (16) _ O _ is missing. If you look at a light through very narrow (28) O _ _ _, you see that the light spreads out and there are dark and bright places. The bright places are (21) O _ _ _ _ and the dark ones are antinodes. This shows that light is made of (1) O _ _ _ _ _. You have to use narrow slits because the wave (2) _ _ _ _ _ O of light is very short.

2. Lenses for inexpensive cameras are like the lenses you used in class. Lenses for more expensive cameras are made of two or more lenses of different kinds of glass. Ask someone who sells cameras why this is done.

3. Why are the lenses of expensive cameras and binoculars coated with a bluish substance?

FOR FURTHER READING

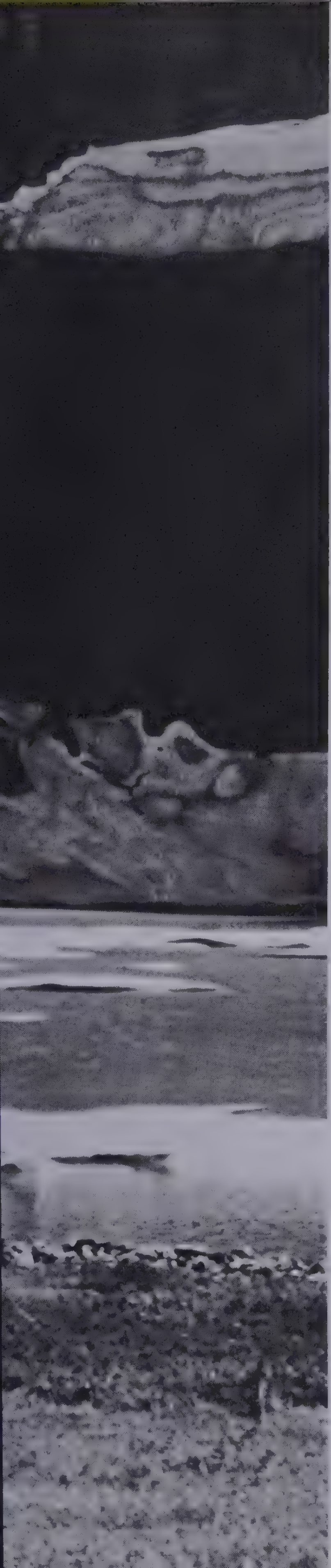
Hellman, Hal. *The Art and Science of Color.* New York: McGraw-Hill, Inc., 1967. Science of color and light. Physical principles of light; relationship of wave-length to color.

Rainwater, Clarence. *Light and Color,* rev. ed. Racine, Wis.: Western Publishing Company, Inc., 1971. From fundamentals of electromagnetic spectrum to color television.

Ruchlis, Hyman. *The Wonder of Light.* New York: Harper and Row, Publishers, 1960. Excellent photographs covering wide range of topics.

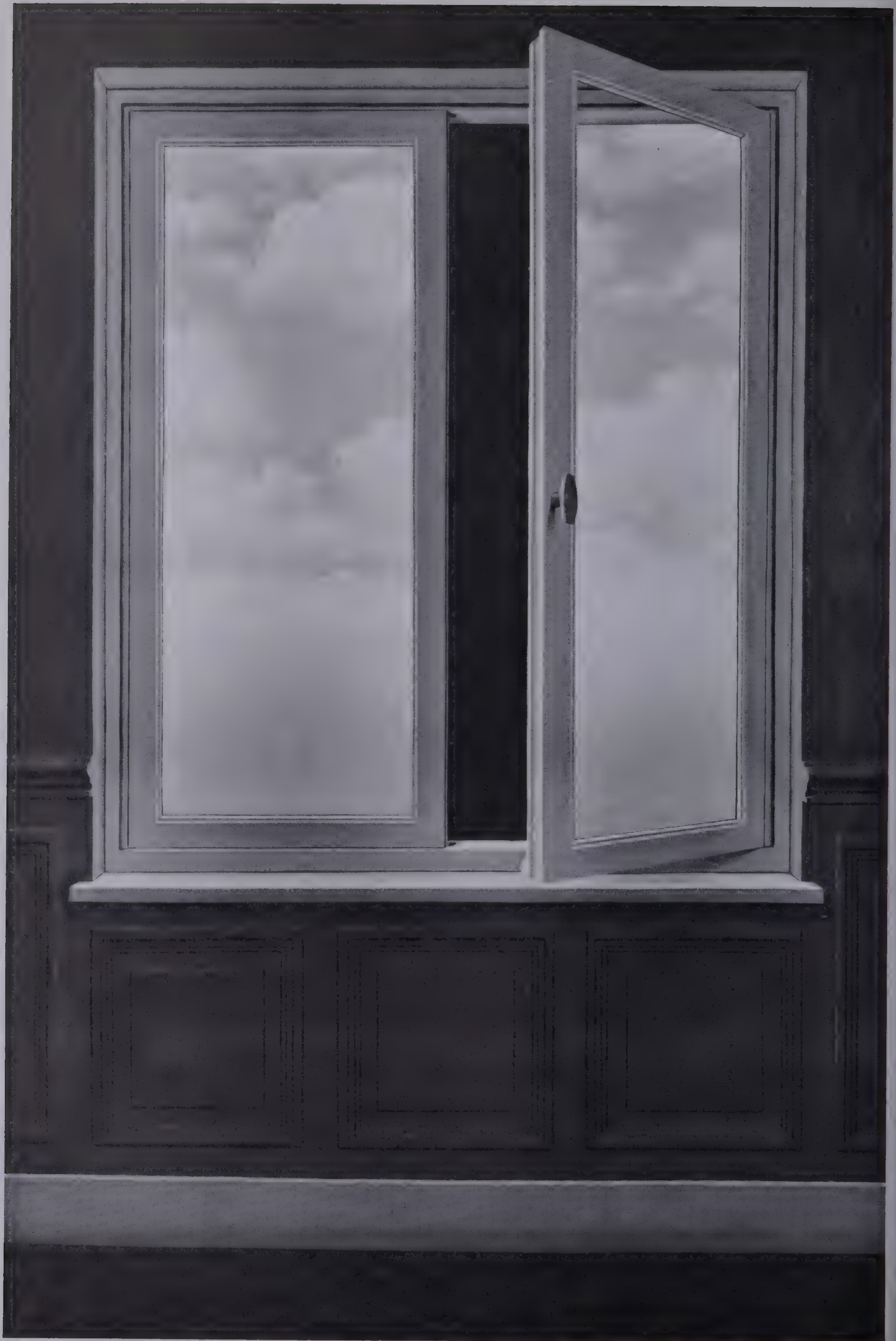
WHAT'S NEXT?

The science of physics, which you have been studying so far, is one of many sciences. Or perhaps it would be better to say one of many branches of science, because all scientists share the same ideas and methods. Physicists and chemists use these ideas and methods to study matter and energy. Only their points of view are slightly different. The physicist is interested in the way matter behaves: the chemist is interested in the way matter changes. And this is the point of view we will be taking in the following chapters.



Unit Five

The Nature of Matter



Chapter 12 Matter

If you take a quick look at the picture on the facing page, you probably won't see anything odd about it. But if you look more carefully, you will see something unusual. Through the glass, there is a sky full of clouds. But through the open window, there is only darkness.

You know at once that this could not happen in the real world. But the artist who painted this picture, René Magritte, has made it happen in his painter's world.

In some ways, artists have an easier time than scientists. An artist can paint or draw something the way it really is. Or he can change it slightly, if he feels like it. Or he can make up something out of his imagination that could never exist anywhere but in his mind. You know, and Magritte knew, that you can't really see one scene through the glass of a window and a different scene through the open window. But you can in the world of the artist's imagination, where there are no rules.

A scientist must have imagination too, or there would be no new ideas in science. But the world of the scientist's imagination has the same rules as the real world. A scientist must spend some of his time figuring out what is possible and what is impossible. And, unlike the artist, the scientist must choose to explore what is possible, what works according to the rules.

Measuring Matter

12-1 Weight and mass

Very few people are happy with their weight. Many people want to lose weight and others try hard to gain. Having to diet isn't much fun. The men who went to the moon each lost more than a hundred pounds. Of course, they gained it all back when they came back to earth.

Suppose your weight is 120 pounds here on earth. What would you weigh on the moon? Would you ''feel'' thinner? Would you look thinner? Suppose you have a mass of 60 kilograms on earth. What would your mass be on the moon?

The weight of an object is a measure of the pull of gravity. The pull of gravity can vary from place to place, so weight can vary from place to place. The mass of an object does not vary with the pull of gravity. Mass is a more useful measure to use in scientific work. Weight can be used but only if all the measurements to be compared are made at the same place.

12-2 How can space be measured?

Are weight and mass the only ways to measure matter? People don't buy liquids like milk by the pound or the kilogram. They buy them by the quart or the gallon. In a recipe, many ingredients are given in cups and teaspoons. Quarts, cups, and teaspoons are all measures of volume. **Volume** is the amount of space an object takes up.

You can buy a quart of milk in a cardboard container. You can also buy a quart of milk in a glass bottle. The containers have different shapes. But they hold the same amount (volume) of milk.

In the metric system, volume is measured in **liters** (LEE-ters). A liter is a little larger than a quart. There is more milk in a liter of milk than in a quart of milk.

At home you use a measuring cup to find the volumes of liquids and some solids like flour. Scientists have a special kind of measuring cup (Figure 12-1A). It is called a **graduated cylinder,** or **graduate.** Some graduates can measure a liter of liquid. This is too large for most of the ordinary measurements needed. A liter is divided into smaller units called **milliliters** (**ml**). There are 1000 milliliters in every liter (Figure 12-1B). There is a scale on the side of the graduate marked in milliliters.

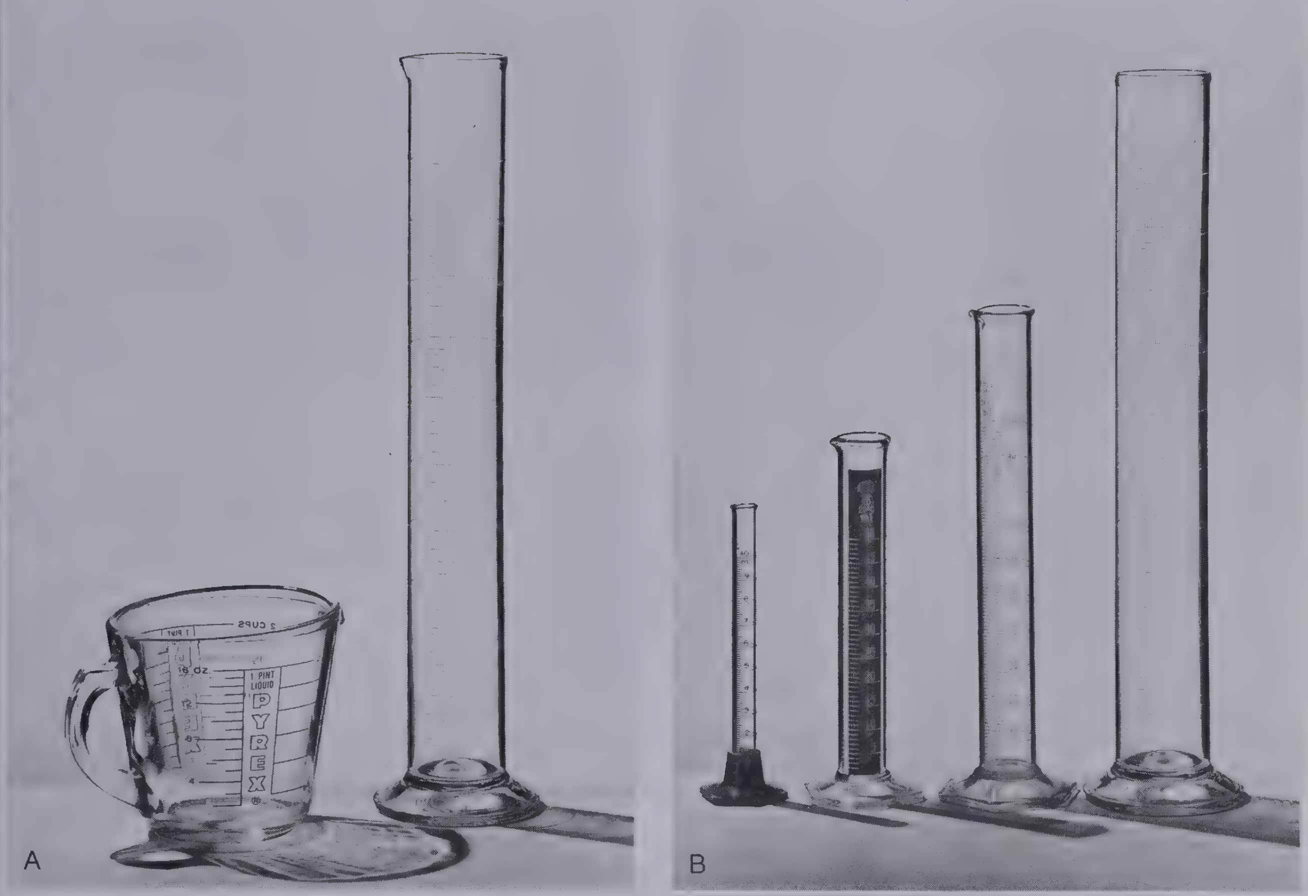


Figure 12-1 (*A*) *These containers have about the same volume. The measuring cup holds a pint. The graduate holds 500 ml.* (*B*) *The smallest graduate shown holds 10 ml. Why wouldn't you use the same size graduate all the time?*

12-3 Measuring the volumes of liquids

Materials
graduate

★ Fill your graduate about half way with water. Put the graduate on a level surface. Bend down until your eyes

Figure 12-2 *Don't try to hold the graduate up to your eyes.*

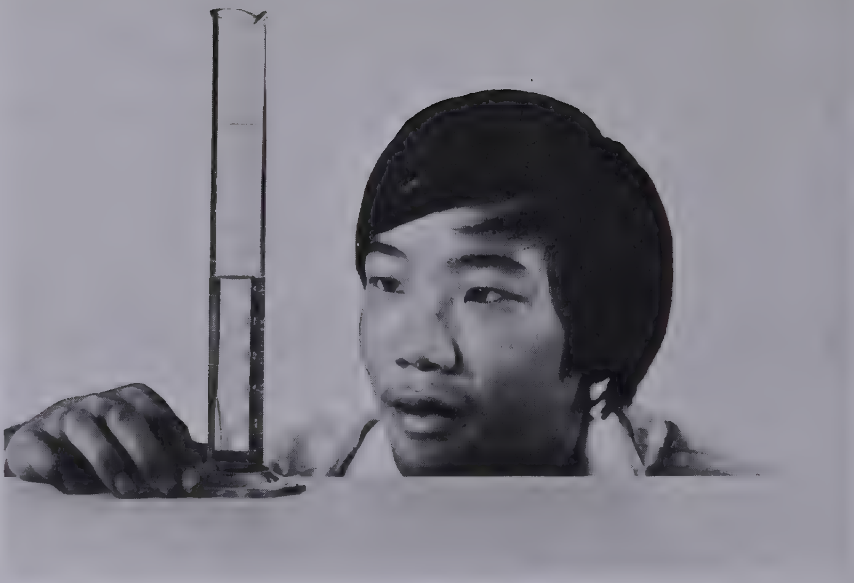
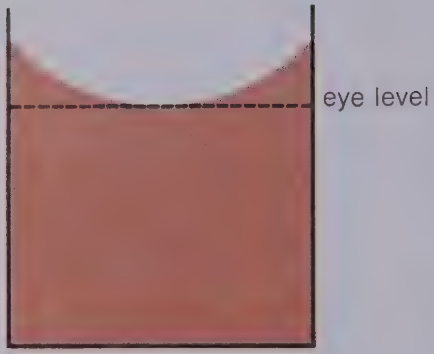


Figure 12-3



are at the same level with the water (Figure 12-2). The surface of the water is curved. Make a reading at the bottom of the curved surface (Figure 12-3).

What happens if you make your reading above eye level? What happens if you make your reading below eye level? Always take readings at eye level and read the bottom of the curve.

What if the bottom of the curve is between two lines? Would you call the volume in Figure 12-4A 12 ml, 13 ml, or 12.5 ml? Is the volume in Figure 12-4B 38 ml, 38.5 ml, or 39 ml? Always make your readings to the nearest half milliliter. ★

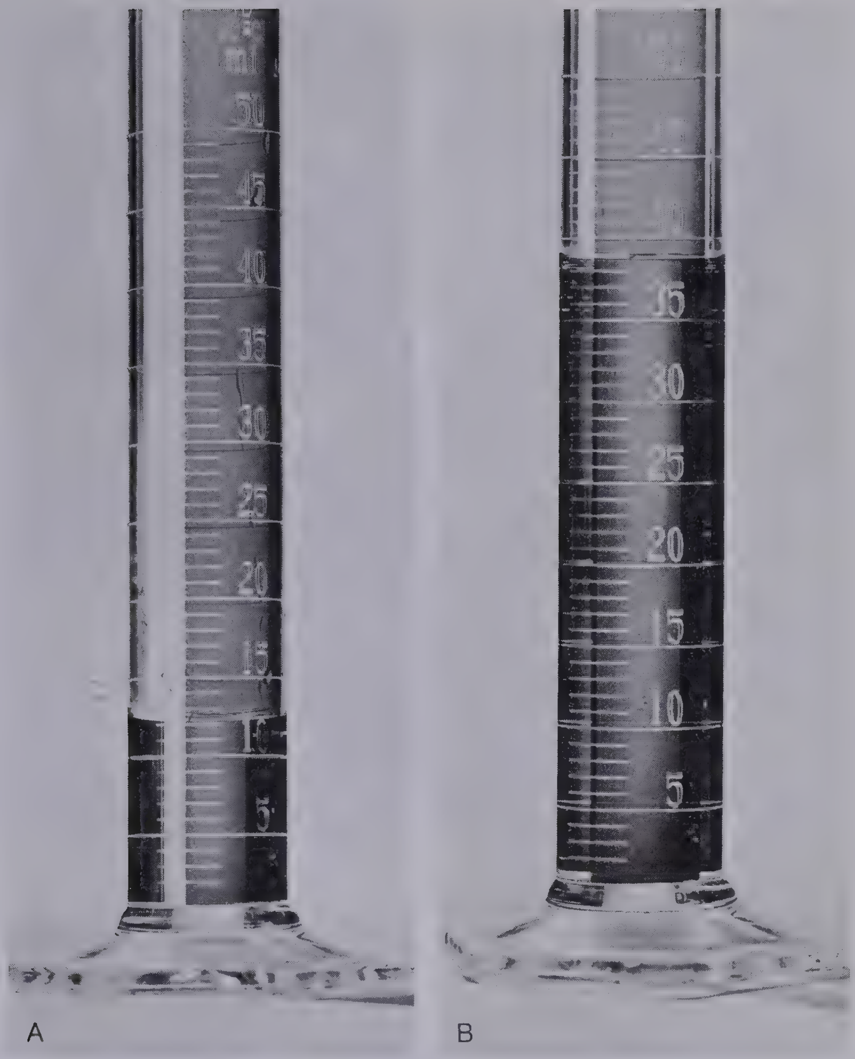
12-4 Measuring the volumes of solids

The volumes of some solids, like salt and sugar, can easily be measured in a graduate just as they are in a measuring cup. But what about a block of wood or a marble? How can you measure their volumes? It would be silly to ask for a liter of wood.

Materials
sand, graduate, ice-cube tray, clay

★ You need another method for measuring volumes of solids. Measure 50 ml of sand in your graduate. Use the sand to completely fill small plastic cubes such as the cubes

Figure 12-4 *(A and B) Can you measure the volumes of these liquids?*

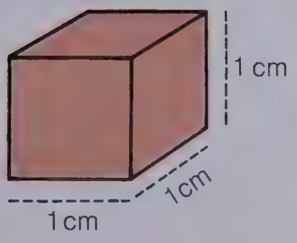


in a plastic ice-cube tray, one at a time. How many cubes of sand are there in 50 ml of sand?

Now take a ball of clay. Find its volume in plastic cubes. You used the plastic cube as a unit of volume. But is it a good unit to use? No one outside your class would know how much clay equaled, say, ten plastic cubes. The milliliter is a better unit because it is a standard unit. ★

A **standard unit** is a unit that people have agreed to use. Scientists work with a standard cube called a **cubic centimeter** (**cm^3**). It is a cube that is one centimeter on each side (Figure 12-5). One milliliter of water would just fill one cubic centimeter. One ml equals one cm^3.

Figure 12-5 *One cubic centimeter.*



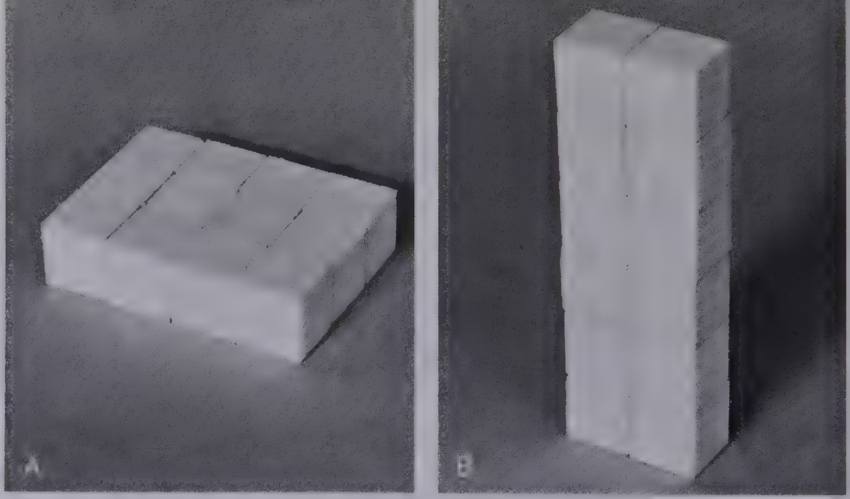


Figure 12-6 *How will you find the volumes of these shapes?*

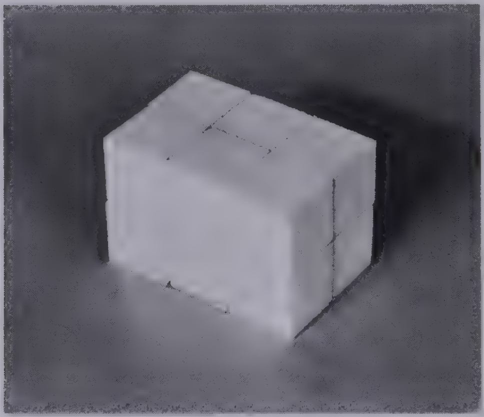


Figure 12-7 *Another regular solid.*

Materials
12 cubes, 1 cm^3 each

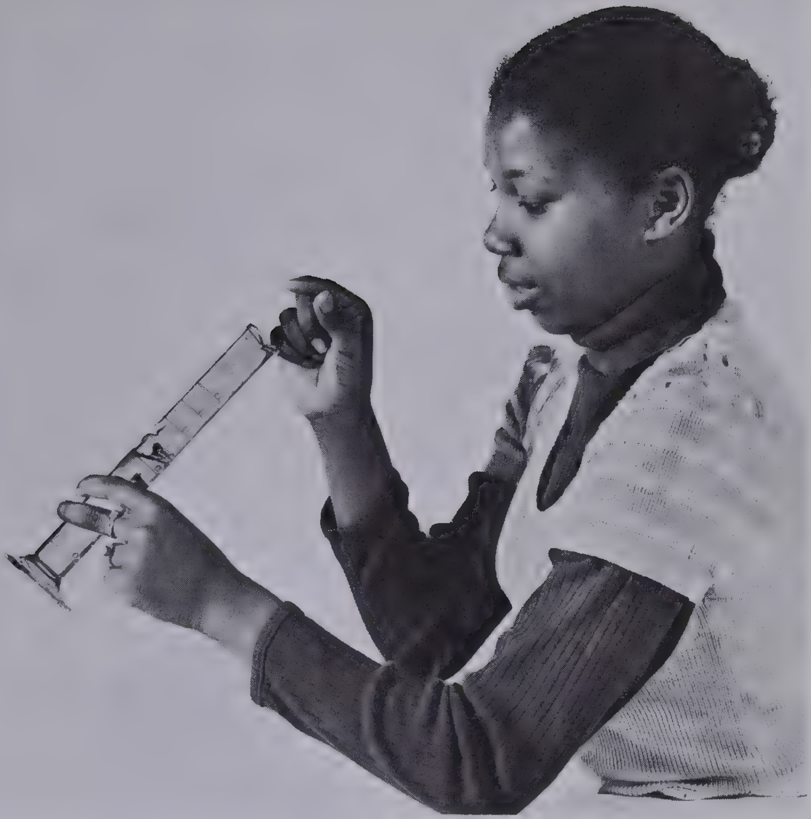
★ Look at Figure 12-6. Make each of the arrangements with your 12 cubes. How much space is taken up by each arrangement? Make other arrangements with your cubes. Make a drawing of each arrangement and write down its volume. Explain how you find each volume. Do you have to count all the cubes to find the volume of each arrangement? ★

The arrangements that you made with cubes were all regular solids. **Regular solids** have sides that can be measured with a ruler. Suppose you made the arrangement shown in Figure 12-7. Its length is 3 cm, its width is 2 cm, and its height is 2 cm. You can find its volume by multiplying length × width × height.

$$3 \text{ cm} \times 2 \text{ cm} \times 2 \text{ cm} = 12 \text{ cm}^3$$

This method works for any regular solid. Find the volume of this book in cm^3.

Figure 12-8 *Remember that 1 ml equals 1 cm³.*



12-5 Can you measure the volume of an irregular solid?

Look at your pebble. Can you use a ruler to find its volume? A pebble is an **irregular solid.** Its sides cannot be measured simply.

Materials
pebble, graduate, water, dropper, blocks

★ Fill your graduate halfway with water. Read the water level in your graduate. Use a dropper to add just enough water to make a whole number of milliliters. Record the volume of the water in your graduate.

Make three or four blocks that each have a volume of 1 cm³. Tilt the graduate. Slide one block into the graduate (Figure 12-8). Do not spill any of the water. Take another reading. Carefully add the other cubes, one at a time. Take a reading each time. How did the change in the volume of water compare to the volume of the clay cubes? Now, use the same method to find the volume of the pebble. Measuring volume by this method is called the **displacement of water.** ★

12-6 Can you measure the volume of a gas?

Materials
large pan or cardboard paint bucket, water, food coloring, small bottle or beaker, rubber tubing, soda straw

★ Fill your large container halfway with colored water. Fill the small bottle with colored water as shown in Figure 12-9. Keeping the mouth of the bottle under water, turn it upside down in the container. Put one end of the rubber tubing into the small bottle. Put a soda straw in the other end of the rubber tubing. Blow into the soda straw. What happens? Do you think air is matter? ★

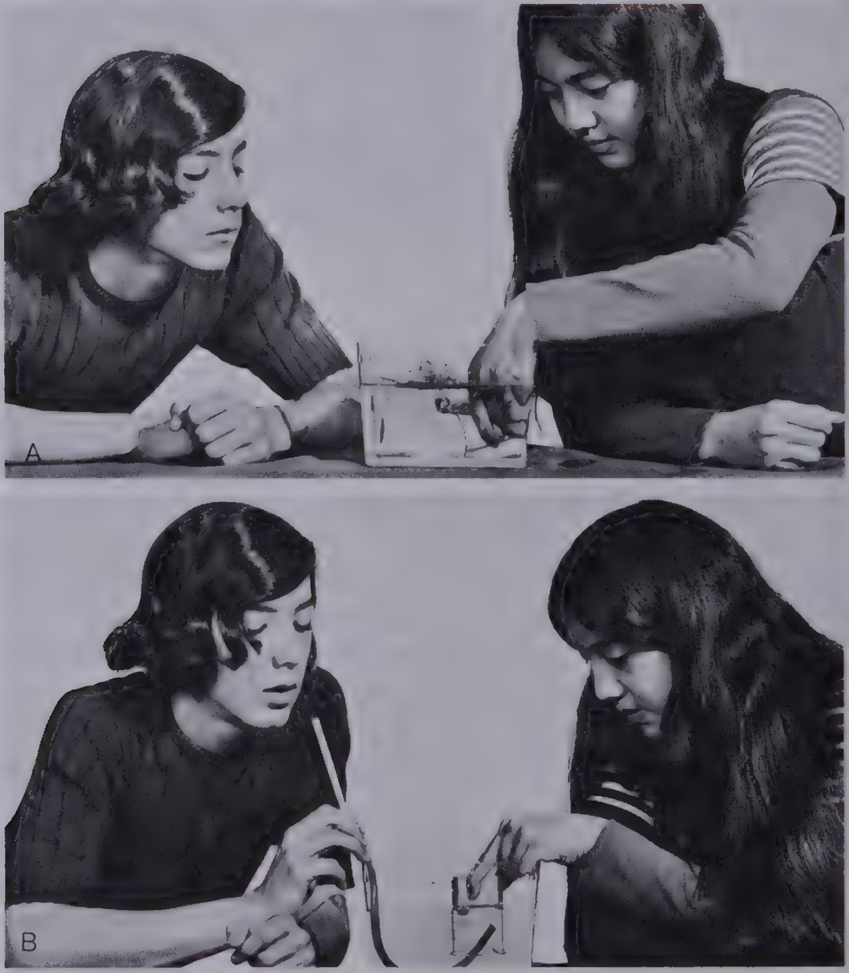


Figure 12-9

Did You Get the Point?

The weight of an object changes with the pull of gravity.

As a measure of the amount of matter mass is more useful than weight.

The volume of an object is the amount of space taken up by that object. Volume is another measure of the amount of matter.

The volume of a regular solid can be found by measuring with a ruler and using simple arithmetic.

The volume of an irregular solid can be found by the displacement of water.

Air takes up space. Air is matter.

What Have You Learned?

1. Is length a measure of the amount of matter?

2. How would you measure the volume of (a) a sugar cube, (b) maple syrup, and (c) a gold ring?

3. Why are potatoes sold by weight and gasoline by volume?

4. Why is mass more useful than weight as a measure of the amount of matter?

Properties of Matter

12-7 What is a property?

What is purple and hums?
An electric grape.

This is a riddle, and like all riddles the answer is a surprise. If you wanted to find the answer, you might try thinking of all sorts of purple things and then try to figure out which of those hummed. Or you might try thinking of things that hum and figure out which of those are purple. What you are looking for is something that has the two properties

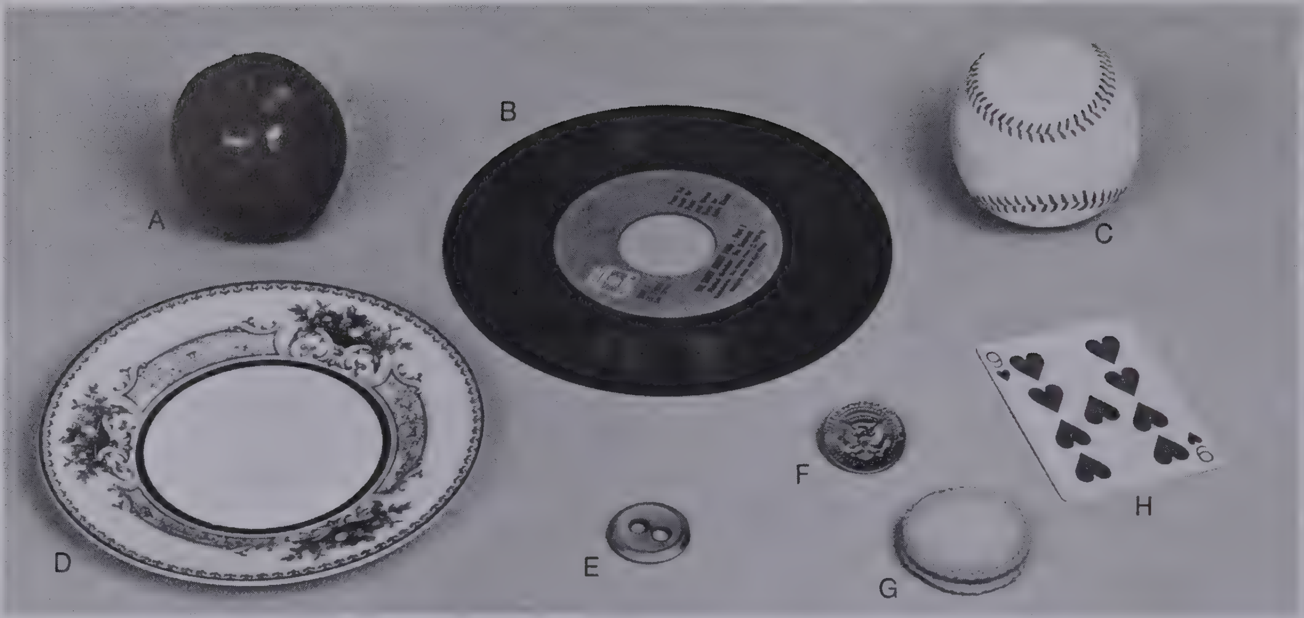


Figure 12-10

of being purple and of humming (and, of course, you are not really supposed to come up with the right answer).

Properties tell you such things as what an object looks like, what it is made of, or how it acts. Properties are used to identify objects. When you play ''Twenty Questions,'' you ask about the properties of the subject to guess the right answer.

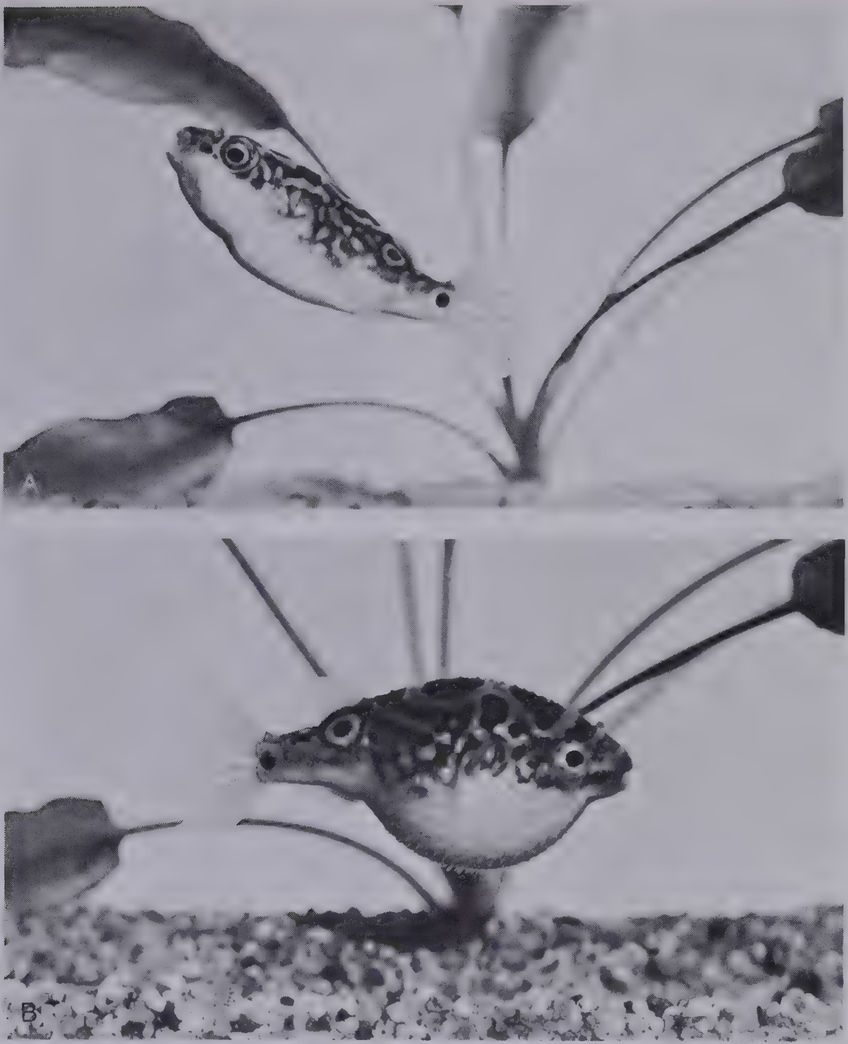
Here are some properties of one of the objects in Figure 12-10. It is round. It is flat. It is not good to eat. It could fit easily in your hand. It is shiny. Which one must it be?

Did you know enough of the properties to be sure? The more properties you know, the more certain you can be of identifying an object.

12-8 The limits of volume

There are two properties that all materials have in common. They all have mass and they all have volume. But volume can be tricky. Look at the fish in Figure 12-11. How could you measure its volume? The volume isn't always what it appears to be.

Figure 12-11 *Believe it or not, this is the same puffer fish. When a puffer is frightened, it swallows air or water and blows up like a balloon.*



Materials
sponge, metric ruler, pan, water

★ Measure the length, width, and height of the sponge. Then use these measurements to find its volume. You found the volume of the sponge. But is it the volume of the material called sponge? Fold the sponge in three parts. Press down on the folded sponge as hard as you can. Find the volume of the folded sponge. Is this volume larger or smaller than the first volume you measured? What made the difference?

The sponge material takes up only part of the original space you measured. Put your sponge under water and squeeze it. What other material takes up the rest of the space? What material takes up the space when the sponge is dry? ★

Materials
balloon, Erlenmeyer flask, wire gauze, stand, burner, clamp

★ Your teacher will stretch the mouth of a balloon over the neck of a flask, and will heat the flask as shown in Figure 12-12. What happens? Does the volume of the balloon change? Why? How does heat affect the volume of air? What property of the balloon lets the volume change? ★

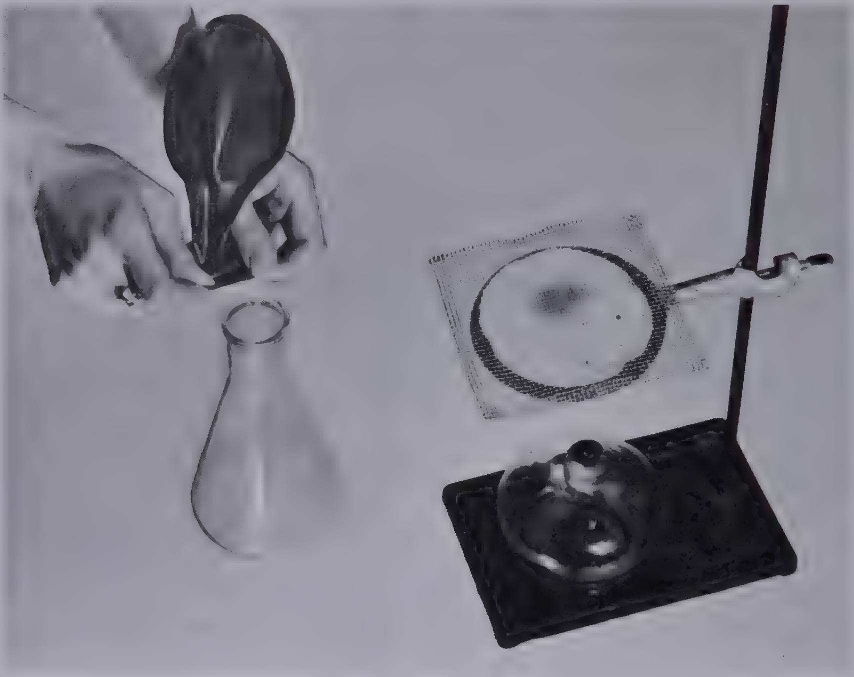


Figure 12-12 *What will happen when the flask is heated?*

Materials
air pump, 2 pieces of rubber tubing, 2 clamps

★ There is a hand pump at the demonstration table. Compare it to the diagram in Figure 12-13. Find the air intake opening and the air outlet opening. The handle of the pump is connected to a piston. A **piston** is a sliding part that changes the volume of air inside a cylinder.

Place one piece of rubber tubing on the air intake opening and another on the air outlet opening. One person will hold his finger near the opening of the air intake tube. A second person will hold his finger near the air outlet tube. A third person will move the handle so that the piston moves up and down. What happens as the piston moves up and down?

Push the handle halfway down. Put a clamp on both pieces of rubber tubing. What do the clamps do?

When you move the handle up and down with the clamps in position, does the amount of air in the cylinder change? Does the volume of the air change? ★

Materials
2 graduates, beaker of water, dropper, beaker of alcohol

★ Pour 20 ml of water into a graduate. Pour the same amount of water into a second graduate. Use a dropper to make sure there are exactly 20 ml in each graduate. Pour the water from one graduate into the other. If any water spills, start over again. Measure the combined volume. Empty the graduates.

Pour exactly 20 ml of water into one cylinder. Pour the same amount of alcohol into the second cylinder. Pour the water into the alcohol. If any water spills, start over again. Measure the combined volume. Was there any change in volume? ★

Volume is a tricky property to measure. Why use it at all? Why not always use mass?

It is much easier to measure the volume of a liquid or a gas instead of its mass. If you remember to correct for the limits of volume, volume is a very useful measurement.

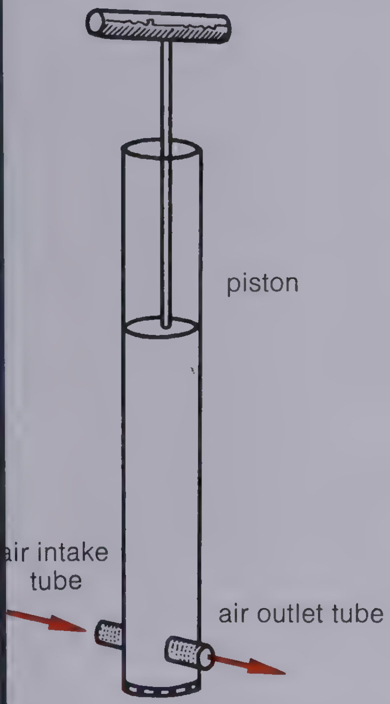


Figure 12-13 *A hand pump.*

12-9 Matter and energy have different properties

Some things cannot be bought or sold by mass or volume. Electricity can't be measured in grams or cubic centimeters. Neither can heat. Electricity and heat are not kinds of matter. They are types of energy. Energy is measured by the amount of work it can do. The ability to do work is a property of energy. It is not a property of matter.

Did You Get the Point?

Properties tell you such things as what an object looks like and how it acts.

Mass and volume are properties of matter.

The same amount of matter can take up different amounts of space.

Some of the space that seems to be occupied by a material is actually filled with air or some other materials.

Matter and energy have different properties.

What Have You Learned?

1. What are some of the problems you find when you use volume as a measure of the amount of matter?

2. Why is mass often a better measure of the amount of matter than volume?

3. What kinds of matter can be measured by volume? Why?

SKULLDUGGERY

1. If your family doesn't object, you can compare the amount of matter your family buys each week to the amount of matter that is thrown away. Find the weight of all items that your family buys or is given during one week. During the same week keep track of the weight of things that are thrown out. If you have a garbage disposal, how will this change your results? What are some other things that might change your results?

2. Design a way to find out whether you get the same amount of food when you buy it fresh, canned, or frozen. Suppose you choose to compare the green peas in fresh pods to the green peas in a can or in a package of frozen peas. You might count each pea. Or you might use what you have learned about measuring mass and volume. If it is possible, try out your method and see what happens.

FOR FURTHER READING

Berger, Melvin. *For Good Measure.* New York: McGraw-Hill, Inc., 1969. Problems and techniques in the field of measurement.

Lefkowitz, R. J. *Matter All Around You: A Book about Solids, Liquids, and Gases.* New York: Parents' Magazine Press, 1972. A good elementary explanation of the states of matter.

Stambler, Irwin. *Build the Unknown.* New York: W. W. Norton and Company, Inc., 1963. How scientists create the materials of tomorrow.

WHAT'S NEXT?

Mass and volume are properties of all matter. But suppose you have an object with a mass of 5 g. It could be almost anything. Suppose you have an object with a volume of 10 ml. Again, it could be a million different things. In the next chapter you will learn about a property of matter that is based on both mass and volume. You will find that the new property can be used to tell one kind of matter from another.

Chapter 13

Mixtures and Substances

Iron ore is rusty red stuff. You would never guess, just from looking, that iron comes from it. Iron is taken from its ore by heating the ore in huge furnaces like the one in the photograph. You can see these furnaces lighting up the night sky around such cities as Pittsburgh, Cleveland, and Birmingham.

After it is melted out, the iron can be poured into molds to make cast iron bathtubs and machine parts. But cast iron is not the most useful form of iron. It cracks too easily because other chemicals, mostly carbon, are still mixed with the metal.

More powerful furnaces are used to burn off most of the carbon and make steel. To make steel even more useful, chemists add other metals to it. A mixture of metals is called an **alloy.** A tough, hard alloy of steel and nickel is used for making safes and armor plate and the machine tools that cut other metals. An alloy of steel and chromium is stainless steel, which you can probably find at home in the kitchen. The steel that is used for magnets and automobile springs contains silicon.

Even coins are now made from hard alloys instead of pure gold, silver, and copper. One of our coins is named for one of the metals in it. The next time you want to borrow five cents, you may think you are getting a nickel make of nickel. What you are really getting is a nickel-copper alloy.

That is, if you can find anyone who will lend it to you.

Mixtures

13-1 Recognizing mixtures

Many mixtures are easy to recognize. Look at the pictures in Figure 13-1. Is the rock in Figure 13-1E a mixture?

Materials
paper, white material (from teacher)

★ Look carefully at the white material on your sheet of paper. Is it a mixture? How did you decide? Put a few small pieces of the material on your tongue. **Caution: Never taste materials in a laboratory or classroom unless you are told to do so. When you do taste any material, taste only very small amounts.** What did you learn from tasting your sample? Are all mixtures easy to recognize?

Materials
calcium acetate, water, alcohol, 2 graduates, beaker.

★ Put 30 ml of alcohol in a beaker. Use a second graduate (or clean the first one and use it again) to measure 5 ml of the calcium acetate and water mixture. Add the calcium acetate and water to the alcohol. What happens? ★

You have made a material called "Sterno." People use this mixture for cooking when they go camping or to keep food warm at a party.

After you make the Sterno, it is hard to tell that it is a mixture by simply looking. Your teacher can demonstrate that Sterno is a mixture by burning it. Which ingredient burns? Which material is left when the burning is over? What happens to the third ingredient?

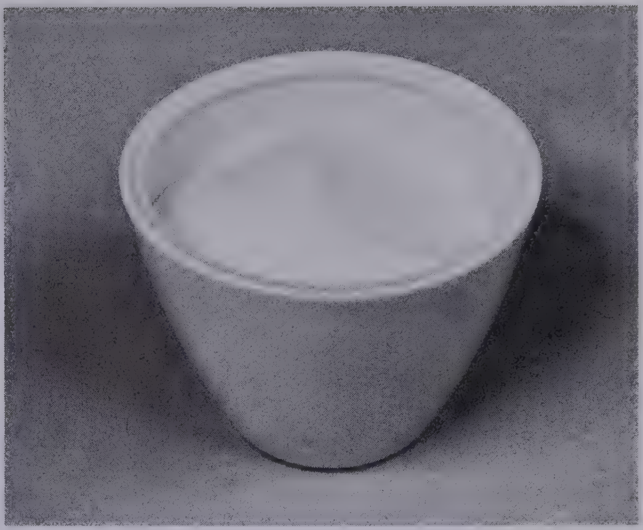
13-2 The properties of a mixture

Materials
water, cup, sugar, lemon juice, dropper, spoon

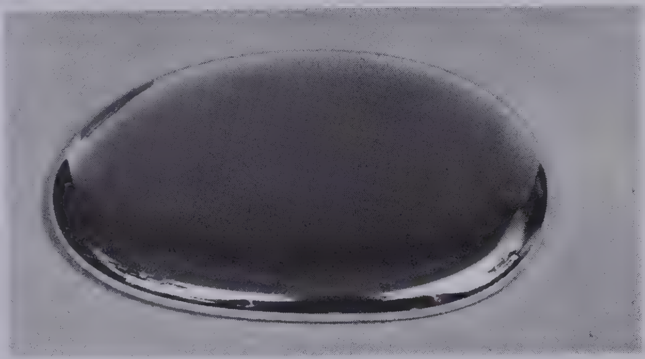
★ Lemonade is a familiar mixture. Start with $\frac{1}{2}$ cup of water. Add small amounts of sugar and lemon juice. Keep a record of how much of each material you use. Measure the sugar in $\frac{1}{4}$ teaspoonfuls and the lemon juice in drops. Each time you add either one, taste a drop of the mixture. Stop when you like the taste. How much sugar did you add? How much lemon juice?

Let other students taste your lemonade. Taste four or five different mixtures. Do they all taste the same? Did everybody use the same amount of sugar? of lemon juice? Does the amount of each material in a mixture always have to be the same? ★

(A) *Pizza is a mixture.*



(B) *Sugar is not a mixture.*



(C) *Mercury is not a mixture.*

(D) *A salad is a mixture.*

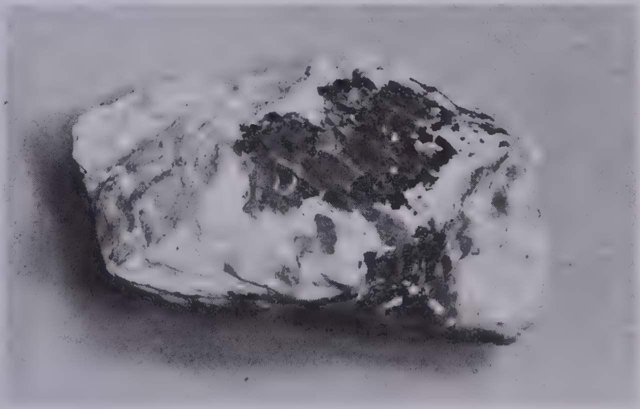


Figure 13-1

(E) *Is this rock a mixture?*

Materials
plastic fork, plastic spoon, paper cup, egg white, salt, powdered sugar, food coloring, food flavoring

★ Does egg white have a color? a flavor? a smell? Is it a liquid or a solid? List as many of its properties as you can in your notebook. Do the same for salt and powdered sugar.

Add a pinch of salt to the egg white in your paper cup. Use a plastic fork to beat the egg white until it foams.

Measure a level spoonful of powdered sugar. Pour a little bit of sugar into the egg white. Then beat the egg white. Add a little more sugar and beat the egg white again (Figure 13-2). Continue until all the sugar has been added.

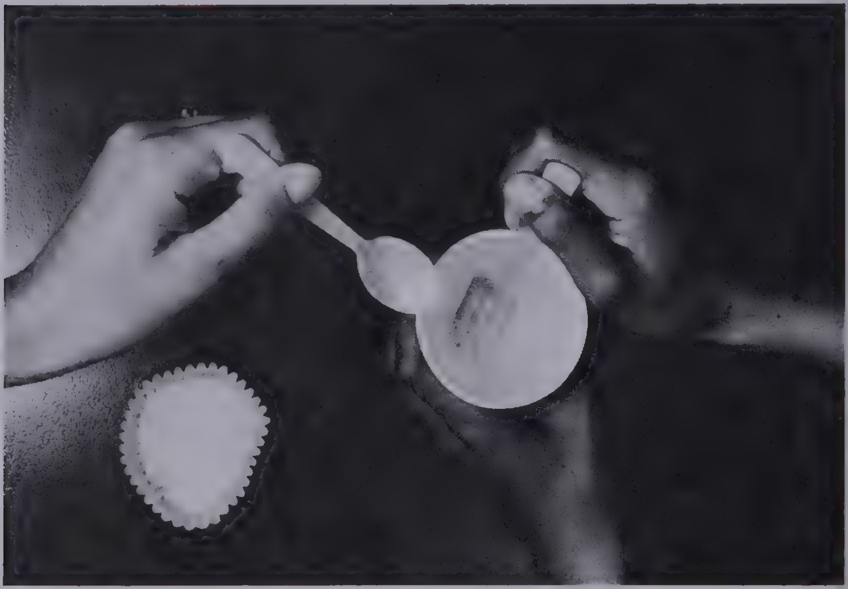
Beat the material until it is stiff. You may need to add one or two more teaspoonfuls of sugar. Taste a tiny bit of the material.

Put a drop of flavoring on your teaspoon and taste it. Add the flavoring to your mixture one drop at a time. Stir the material and taste it. Keep adding flavoring until you like the taste.

Wash and dry your spoon. Pour a drop of food coloring into the spoon. How dark is the food coloring? Add the coloring to your mixture, one drop at a time. Keep stirring the mixture. Do not add the next drop until all the material is an even color. Do not use more than 5 drops.

The material in your paper cup is a mixture. Taste it. What are the properties of your mixture? What would have happened if you had used a teaspoon of salt and a pinch of sugar? ★

Figure 13-2 *Making a mixture.*



MELTER

The steel industry employs about half a million people. One of the key people in a steel-making plant is the Melter, sometimes called the Mixer. The Melter runs the mixing machines that blend limestone, iron ore, scrap steel, and molten pig iron that go into the steel. By varying the amounts of the ingredients, he controls the quality of the steel produced. The Melter can make steel that has special properties by adding small amounts of other materials to the mixture. Manganese, silicon, and copper are often used in this way.

The Melter supervises helpers that prepare the furnaces, control the furnace temperature, and take samples of molten steel for laboratory tests. They operate the giant ladles that pour the molten steel into molds.

New unskilled workers are usually high school graduates. They are trained for their jobs at the plant, but many workers also take part-time courses. When a worker becomes skilled at one job, he can be promoted to a job with more duties and responsibilities. For example, the man who does the general cleanup work around the furnace may advance to third helper, second helper, and first helper. Eventually, he may become a Melter, in charge of the crew.

13-3 Can you separate the materials that make up a mixture?

Materials
rubber band scale, felt tip pen, 3 paper cups, piece of aluminum foil 6″ by 6″, scissors, paper clips, teaspoon or spatula, salt, sand, water, stand, wire gauze, burner, graduate.

Mixing sugar and salt is easy. Making lemonade is easy, too. But how easy is it to take a mixture apart?

★ From a piece of aluminum foil, cut a circle about 10 cm across. See Figure 13-3A. Turn a paper cup upside down. Gently press the aluminum foil against the bottom and sides of the cup as shown in Figure 13-3B. Separate the cup from the foil. Now you have an aluminum foil cup and a paper cup.

Set up the rubber band scale that you made in Section 2-4. Put the aluminum cup into the paper cup of the scale. Mark the zero point on your scale. Put paper clips into the aluminum cup, one at a time. After you add each clip, mark the new position of the pointer. Remember to put a number next to each mark.

Put 3, 4, or 5 clips of sand into the aluminum cup. Then, pour the sand into a separate paper cup. Measure 2 or 3 clips of salt with your scale. Pour the salt into a second paper cup. Write down how much salt and sand you have in the cups.

Examine the sand and salt carefully. Are they easy to tell apart? Carefully mix the sand and salt together in one cup. If you spill any material, you must start over again! Can you still recognize grains of sand and salt in the mixture?

Figure 13-3 *How to make a cup from aluminum foil.*

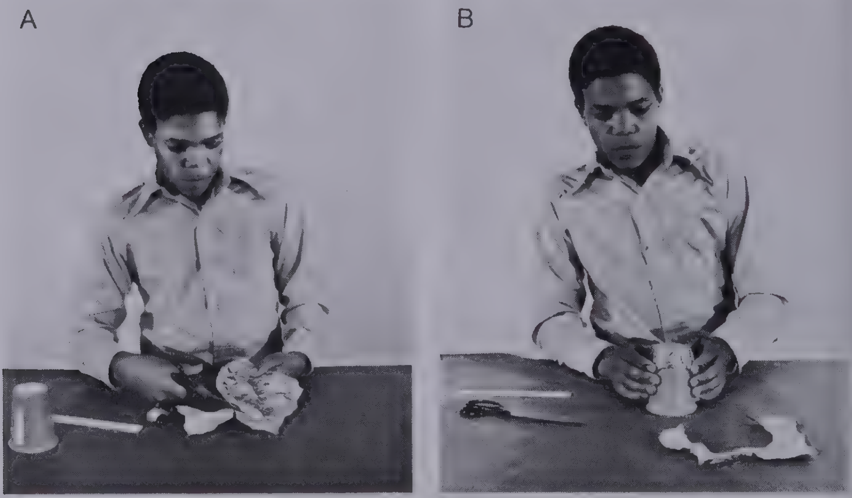
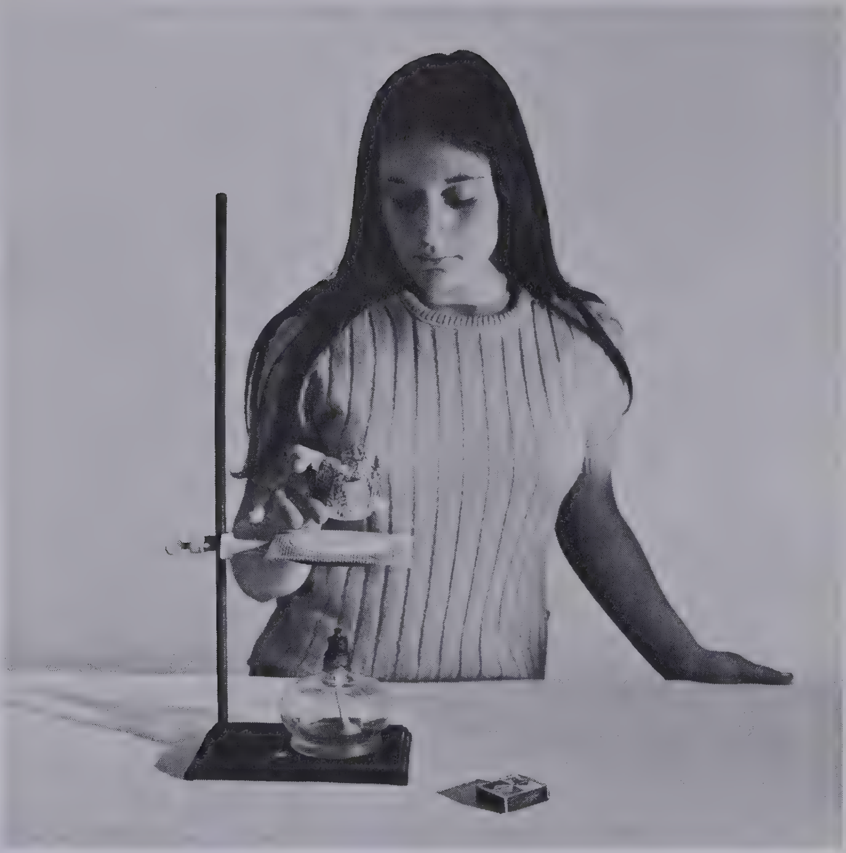


Figure 13-4 *Place the aluminum cup on the wire gauze. Then heat it gently.*



Pour the mixture back into the aluminum cup. How much does it weigh? How does the weight of the mixture compare to the weight of the sand and salt you began with?

Add about 20 ml of water to the mixture in the aluminum cup. Stir the mixture gently. Pour off the water into a paper cup. Be careful not to spill any water. Do not allow any solid to leave the aluminum cup. Add about 10 ml of water to the mixture in the aluminum cup. Stir it and carefully pour off the water into the paper cup. Do the same thing again with 10 ml of water. Leave the mixture in the paper cup for later.

Put the wire gauze on the stand. Set the aluminum cup on the wire gauze as in Figure 13-4. Heat the cup gently until the solid material is dry. Which material does it look like? How much does the dry solid weigh? Pour the solid into a paper cup.

Wash out the aluminum cup. Pour the liquid that you were saving into the aluminum cup. Boil away the water. Use low heat at first. You can increase the heat when the water starts to boil. When the water is almost gone, lower the heat again.

What seems to be left in the cup after the water is gone? How much does the dry solid weigh? What did the salt and sand weigh when you began? What do they weigh now? Try to explain any differences in the weights.

Is the salt different from the salt you started with? What about the sand? What property of salt made it easy to separate from sand? ★

Did You Get the Point?

More than one kind of matter is present in a mixture.

Some mixtures are hard to recognize.

The amount of each material in a mixture can vary.

Each material in a mixture gives some of its properties to the final mixture.

Mixtures can be separated and put back together again.

What Have You Learned?

1. How does the mass of a mixture compare to the mass of the separate materials before they are mixed together?

2. What property does lemon give to lemonade?

3. Is rice pudding a mixture? Is milk a mixture?

Pure Substances

13-4 Can sugar be taken apart?

A mixture of salt and sugar looks like one material. But when you taste the mixture, you get two different tastes. You might guess that the mixture is made of two different materials. What about sugar? Is it a mixture? It looks like just one material. If you break a little piece of sugar into smaller pieces, each tiny piece still looks and tastes like sugar. Sugar is a pure substance. Every bit of a **pure substance** has the same properties as the whole substance.

Mixtures can be separated. Can pure substances be taken apart? Try taking sugar apart.

Materials
coat hanger balance, stand, burner, spoon or spatula, small paper clips, piece of aluminum foil 6″ by 12″, scissors, paper cups, sugar

★ Fold a piece of aluminum foil in half. Cut out two circles, each about 10 cm across. Use a paper cup to make two aluminum cups.

Set up your coat hanger balance. Put the aluminum cups into the paper cups. Adjust your balance so that it is level. Mark the level position.

Place 10 clips in the foil cup on the left side. Add a little sugar to the cup on the right (Figure 13-5). Keep adding sugar until your balance is level again.

Remove the foil cup which contains the sugar. Place it in a small ring on a stand. Be careful not to spill any sugar. Place a burner under the cup and heat it gently (Figure 13-6). Watch the sugar to keep a record of what happens.

Figure 13-5

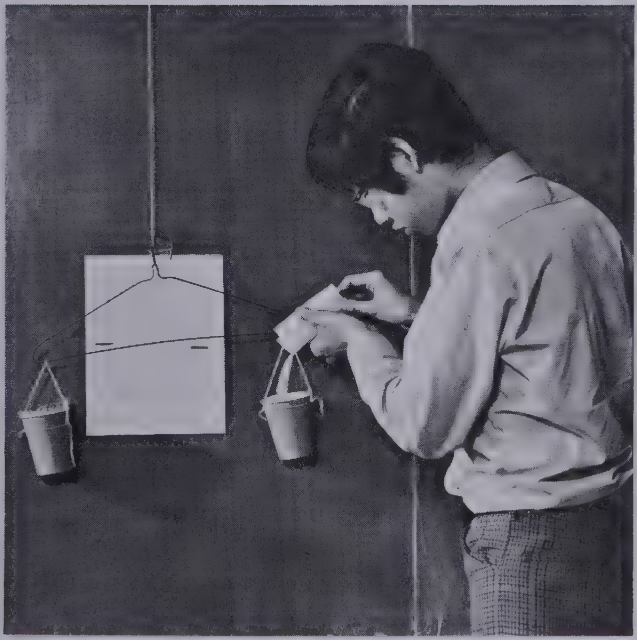
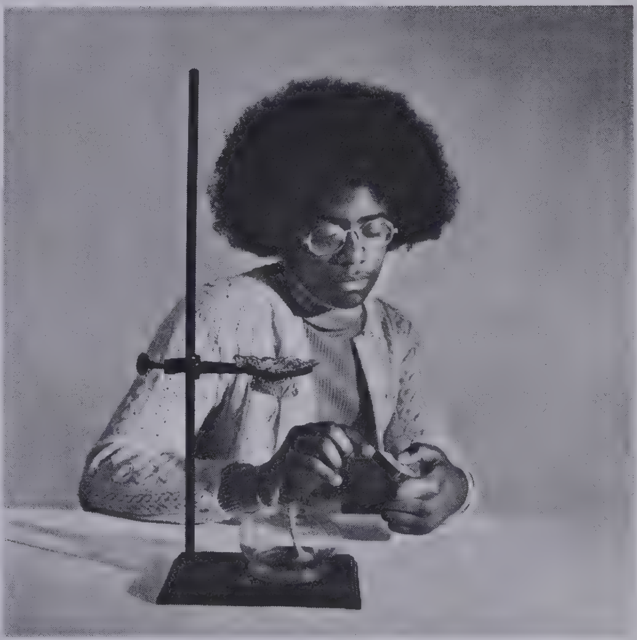


Figure 13-6 *Watch the sugar as it heats.*



Four forms of sugar. When sugar comes from the cane, it looks like the two on the left. You can see that some dark material is mixed with the sugar. Some of the dark material has been removed from the third form. The one on the right is quite pure. You would not call it a mixture.

When all the action in the cup stops, take the flame away. In a few minutes, when the cup has cooled, put it back on the balance. Find the mass of the material left in the cup. Compare that mass to the mass of the sugar you started with. ★

Materials
2 beakers, carbon, water

★ When you take sugar apart, carbon and water are formed. You saw the carbon, but you probably did not notice the water. It was given off as invisible water vapor. If you put carbon and water together, do you get sugar? Try it and see. Does the mixture of carbon and water have the same properties as sugar? ★

Sugar is not a mixture. The carbon and water in sugar are not just mixed together. They are joined in a more complicated way.

13-5 Density

Each pure substance has a set of properties that is different from the set of properties of any other pure substance. A substance can be identified by its set of properties. Remember that mass and volume cannot identify a substance. Almost anything can have a mass of 5 g. Almost anything can have a volume of 20 cm^3. But not everything can have both a mass of 5 g and a volume of 20 cm^3 at the same time.

Materials
coat hanger balance, marking pen, ruler or straight edge, graph paper, graduate, 3 beakers, standard masses, water, benzene, glycerol

★ Set up your coat hanger balance and mark the zero point. Remember that the standard unit for mass is the gram. You will be using objects whose masses are 1 g, 2 g, 4 g, or even larger amounts. Use the left cup for these standard masses. Use the right cup for the liquids. Use a full page to make a table like the one in Figure 13-7.

Figure 13-7 *Your table should have room for up to 25 ml of water, benzene, and glycerol.*

Liquid	**Volume (ml)**	**Mass (g)**	**Density (g/ml)**
Water	5	?	?
	10	?	?
	15	?	?

Use your graduate to measure 5 ml of water. Pour the water into the right cup of your scale. Measure the mass of the water. Measure another 5 ml of water. Add this water to the paper cup. What is the mass of 10 ml of water? Find the mass of 15 ml, 20 ml, and 25 ml of water.

Clean and dry the paper cup (or use a new one). Using benzene, repeat what you did with water. Then, repeat the activity a third time using glycerol.

Make a copy of Figure 13-8 on a sheet of graph paper. Plot your data for water in one color, the data for benzene in a second color, and the data for glycerol in a third. You will end up with three separate lines on your graph. Label each line.

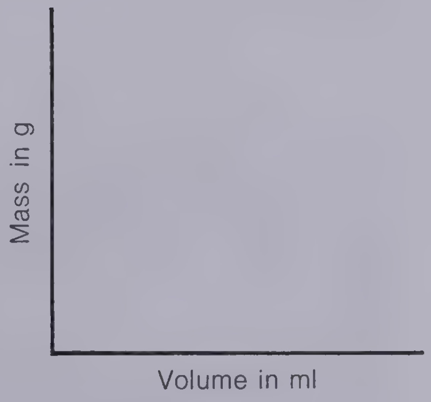


Figure 13-8 *Make a large graph to plot the density of water, benzene, and glycerol.*

The mass of a substance divided by its volume is called the **density** of the substance.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

The unit of mass is grams and the unit of liquid volume is milliliters. The unit of density of a liquid is grams per milliliter (g/ml).

What happens to the mass of water as the volume of water increases? Figure out the density of each sample of water that you used. What happens to the density of water as the volume increases? Figure out the densities of your samples of benzene and glycerol.

Compare the densities of water, benzene, and glycerol. Which of the lines on your graph is the steepest? Which of the materials is the most dense? ★

Mixtures also have densities. A mixture of glycerol and water would have a density between 1.0 and 1.26 g/ml. The exact density would depend on the amounts of water and glycerol in the mixture. The more water, the closer the density would be to 1.0 g/ml. The more glycerol, the closer the density would be to 1.26 g/ml.

You can find the densities of solids, also. The mass of a solid is given in grams. The volume is given in cubic centimeters. What unit would you use for the density of a solid?

Materials
coat hanger balance, graduate, piece of metal, beaker, water

★ Use your balance to find the mass of your piece of metal. Then find the volume by water displacement. Figure out the density. Then use Figure 13-9 to decide which metal you have. ★

Figure 13-9 *Densities of metals.*

Metal	Density
Aluminum	2.7
Brass	8.5
Copper	8.9
Iron	7.9
Lead	11.3
Zinc	7.1

The turning tank of this cement truck makes a mixture of cement, sand, gravel, and water.

Glass is so clear that it looks like a pure substance but really it is a mixture.

13-6 Most common materials are mixtures

Your list of mixtures was probably much longer than your list of pure substances. Even common materials that are called ''pure'' substances are not really pure. Did you have table salt on your list of common substances? The salt you use at home may be iodized. This means that a substance like potassium iodide has been added to the salt to prevent a disease called goiter. Check the container. Are other materials listed?

Did you think that aluminum was a pure substance? Most ''aluminum'' pots and pans are made from alloys of aluminum and manganese. Even clear window glass is a mixture of soda, lime, and silica.

When a material is almost all one kind of matter, it is called an impure substance. An **impure substance** contains small amounts of matter that are different from the substance. Very few substances are really pure. A chemist calls a material a substance if the amount of impurities does not affect his work. When the amount of impurities is large, the material is called a mixture rather than a substance. Most common materials are mixtures.

Did You Get the Point?

Most common materials are mixtures.

Every bit of a pure substance has the same properties as the whole substance.

The density of a substance can help you identify it.

If there are small amounts of other kinds of matter in a substance, the substance is called an impure substance.

What Have You Learned?

1. What is the difference between a pure substance and a mixture?

2. Is sea water a mixture? Is the water you drink a mixture, a pure substance, or an impure substance?

3. Is ice more or less dense than liquid water? Why do you think so?

4. The density of water is 1 g/ml. The density of aluminum is 2.7 g/cm^3. Why doesn't an aluminum boat sink?

SKULLDUGGERY

1. Use the data in Figure 13-10 to solve this problem. Draw a large glass. Show 4 layers of liquids in the glass with the most dense liquid on the bottom and the least dense on top. Then show where each of the solids would be. Would they all sink to the bottom of the glass? Would they all float on the top layer?

Figure 13-10 *Densities of liquids and solids.*

	Material	**Density (g/cm^3)**
Liquids	alcohol	0.79
	glycerol	1.26
	oil	0.90
	water	1.00
Solids	cork	0.2
	marble	2.7
	paraffin	0.87
	rubber	1.1
	tallow (fat)	0.97

2. Visit your local supermarket. Look at the labels of maple syrup and "maple-flavored" syrup. Are these syrups substances or mixtures? If either one is a mixture, what is it a mixture of? Do different brands have the same amounts of each material? How do the prices compare?

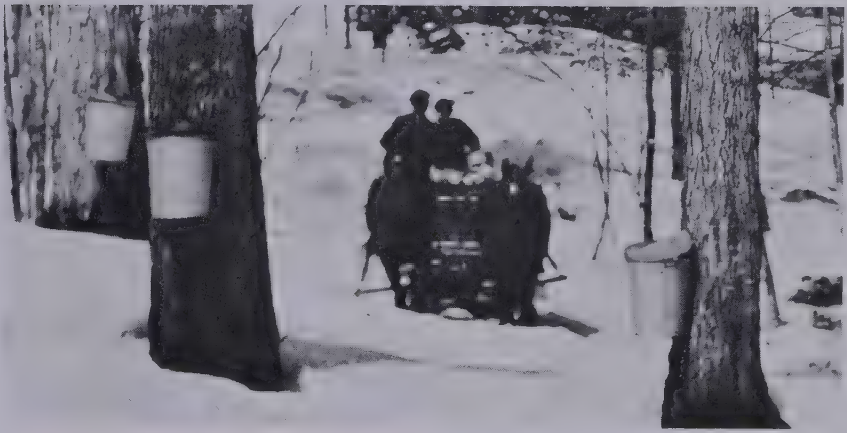


Figure 13-11 *Collecting maple sap. The sap is boiled to evaporate much of the water in it. The liquid that is left is maple syrup.*

FOR FURTHER READING

Butler, Hal. *Millions of Cars: From Drawing Board to Highway.* New York: Julian Messner, 1972. Includes steel and glass-making and assembly-line production.

Carona, Philip B. *Magic Mixtures: Alloys and Plastics.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1963. Includes detailed description of making stainless steel.

McCabe, Charles L., and C. L. Bauer. *Metals, Atoms and Alloys.* New York: McGraw-Hill, Inc., 1964. Discusses processes involved.

Ullyet, Kenneth. *Steel.* New York: Roy Publishers, Inc., 1966. Scientific principles in steel-making.

WHAT'S NEXT?

The world of matter can be divided into mixtures and substances. The world of substances can also be divided. In the next chapter, you will find that aluminum, copper, and lead belong to one group of substances. Sugar, salt, and water belong to a different group.

Chapter 14

Elements and Compounds

What is on the opposite page? You probably said "a cat." But is it actually a cat? Can you feel its fur? Can you hear it purr or snarl?

You are looking at a picture of a cat. A picture is a symbol. A **symbol** is something that stands for an object or an idea. Words are symbols too. The three letters CAT are not an actual cat, any more than the picture is. Both the picture of a cat and the word *cat* stand for the real animal.

Without word symbols you might be able to communicate about objects, maybe by pointing at them. But how could you communicate about an idea without symbols? How could you describe properties such as color or mass? Without symbols, it would be very difficult for you to think. And, it would be impossible for you to speak or write.

Symbols can also be used in place of language. Scientists use many symbols in this way so that they can communicate with each other even though they speak different languages. For instance, chemists all over the world use the same special symbols to stand for pure substances. In this chapter, you will learn some of these special symbols.

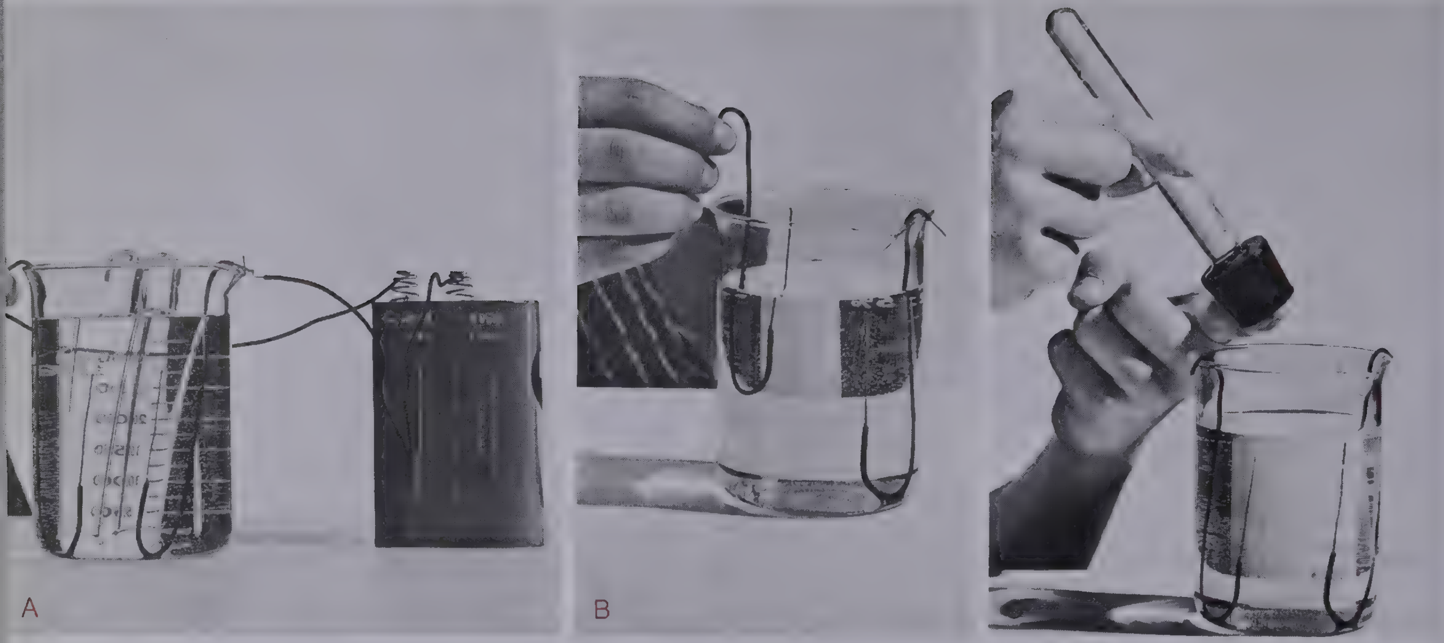


Figure 14-1 *(A) The whole setup. (B) Hook the wires over the edge of the jar. (C) Don't get air in the test tube.*

Recognizing Elements and Compounds

14-1 Water can be taken apart

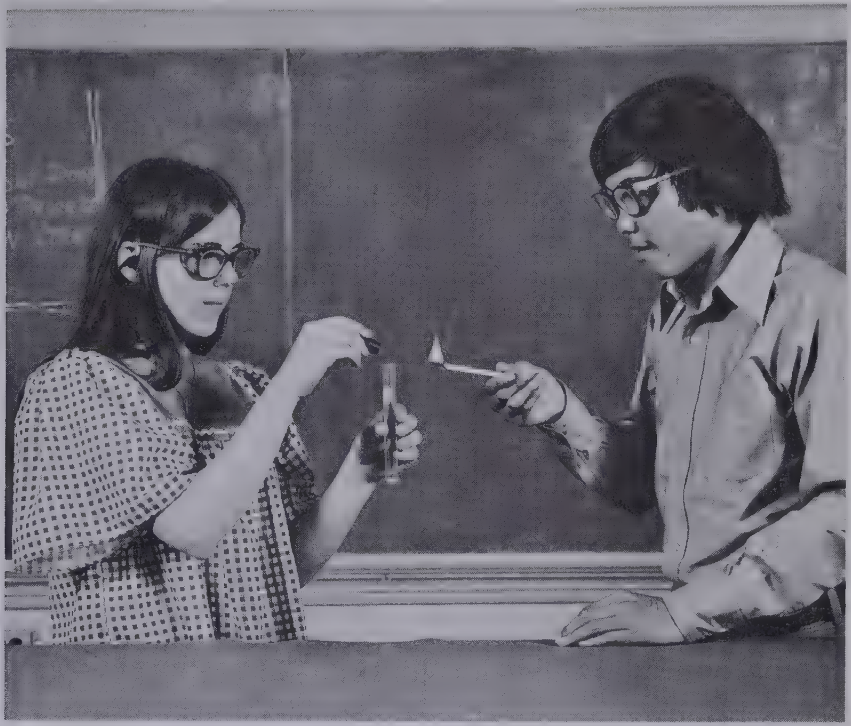
You changed sugar into two other substances, carbon and water, by heating it. But you can't take water apart in the same way. If you heat water, it will boil and become water vapor, which is just water in another form. To break down water, you have to use electricity.

Materials
jar or beaker, water, tablespoon, washing soda, stoppers, wire, 2 small test tubes, 4 dry cells, wood splints, burner

★ Put together the setup shown in Figure 14-1A. Start by filling your jar or beaker two-thirds full of water. Stir in a tablespoon of washing soda. Hook the wires over the edge of the jar as shown in Figure 14-1B.

Completely fill one test tube with water from the jar. Cover the mouth of the test tube with a solid stopper or glass plate. Place the test tube upside down in the jar (Figure 14-1C). After the mouth of the test tube is under

Figure 14-2 *Wear safety glasses when you test a gas.*



water, you can remove the stopper. Place the test tube over one of the wires in the jar. Follow the same steps with the second test tube.

Now connect your dry cells in series. Do you connect the cells positive to positive post or negative to positive? After your teacher has looked at your setup, connect the dry cells to the wires that lead to the test tubes. What happens when the circuit is complete? Near the end of class, you will disconnect the circuit. Does the same amount of gas collect in each tube?

Now test the gases. Carefully stopper each test tube while it is still under water. You will have some water in at least one test tube. Take the test tube with the larger amount of gas. Light a wood splint. Hold the tube upright. Remove the stopper from the test tube and bring the burning splint near the opening (Figure 14-2). What happens? Light a second splint. Blow it out. While it is still glowing, put it in the second test tube. What happens? Be sure to write down the results of these tests. Soon you will be able to use these results to identify the gases. ★

14-2 Can you recognize an element?

If a substance can be broken down into two or more different substances, it is called a **compound.** Water is a compound. Sugar is a compound. Not all substances are compounds. Carbon is not a compound. Carbon is an element. An **element** is a substance that cannot be broken down into different substances. Elements can combine to make compounds. Sugar is made from the elements carbon, hydrogen, and oxygen.

Your teacher will show you two materials. Each of the materials is a substance. Can you tell if they are elements or compounds?

At the moment, you have no way of knowing if a substance is an element. You would have to do more than just look at it. It isn't always easy to show that a substance is a compound. You had to heat sugar to take it apart. You had to use electricity to take water apart.

14-3 Elements have symbols

Scientists know which substances are elements. There are only about 100 different elements. All the compounds in the universe are made from just these elements.

Each element has been given a name. Some of the names, such as carbon and oxygen, you already know. Some, like nobelium and einsteinium, you have probably never heard.

Chemists have also given each element a special symbol. Symbols are a kind of shorthand. C is the symbol for carbon. Zn is the symbol for zinc. If the symbol for an element has two letters, only the first letter is a capital letter. Start keeping a list of elements. Make one column for names, one for symbols, and one for properties.

Did You Get the Point?

There are two types of substances: elements and compounds.

Elements cannot be separated into simpler substances.

Elements can combine to make compounds.

Compounds can be separated into their elements.

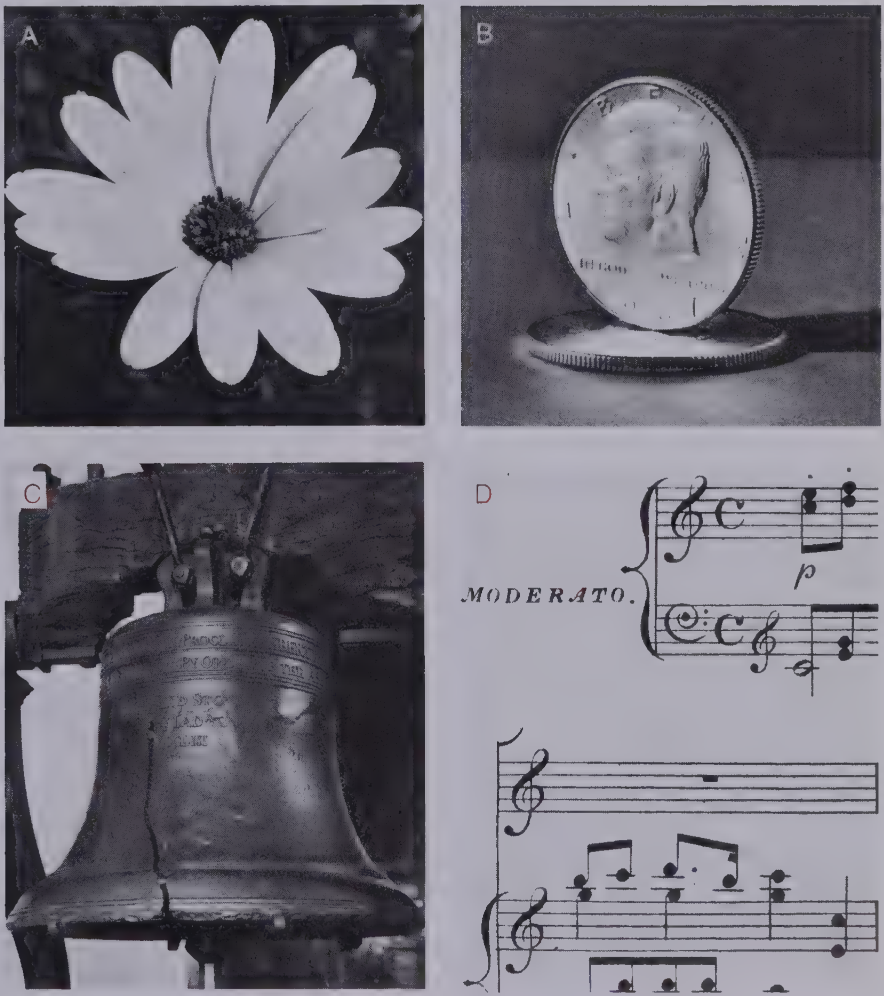
Each element has a symbol.

What Have You Learned?

1. When you took water apart, why did you have to use washing soda? Could you have taken apart plain water?

2. The picture of a flower in Figure 14-3A is a symbol of a real flower. For some people the real flower is a symbol of life or of love. Each month has a flower for a symbol. So does each state. What are the other pictures in Figure 14-3 symbols of?

Figure 14-3 *Use these pictures to answer Question 2.*



Metals

14-4 Properties of metals

Each element has a set of properties that belongs to it alone. Two different elements can share some of the same properties. But no two elements can have all the same properties. If you know the properties of an element, you can identify it.

There are two major groups of elements: metals and non-metals. You are already familiar with a number of metals. You have used iron (Fe) nails, aluminum (Al) foil, and copper (Cu) wires.

Copper is a good conductor of electricity. All metals can conduct elecricity, but some do it better than others. Metals also are good conductors of heat.

Materials
iron (Fe), aluminum (Al), copper (Cu), zinc (Zn), lead (Pb), fine sandpaper, magnet, tweezers, burner

★ Look carefully at each metal strip. Clean the surface of each strip with sandpaper. Do the clean surfaces look different from the original surfaces?

If a metal is easy to scratch, it is called soft. If a material is difficult to scratch, it is called hard. Which is harder, iron or lead? Bring a magnet near each strip of metal. What happens? Use tweezers to hold each strip of metal in the burner flame. What happens to the strip? ★

The shininess of a metal depends on the amount of light reflected and the way the light is reflected from the surface. If a shiny metal is also rare, it can be valuable. One rare material is gold, the element with the symbol Au.

Mercury is a metal. Its symbol is Hg. How is mercury like the other metals you have studied? How is it different?

14-5 Metals can form compounds

Why did you have to scratch the metals before you could see them shine? What was on the surface of the metal strips? The next activity should help you answer these questions.

Materials
stand, wire gauze, paper, plastic spoon, aluminum, zinc, iron, paper cups, water, salt, dropper, burner

★ Set up your stand. Place a wire gauze with an asbestos center on it as shown in Figure 14-4A. Place half a spoonful of powdered aluminum near the edge of the asbestos. Place half a spoonful of aluminum on a clean sheet of paper. Label the aluminum on the paper Al. Clean

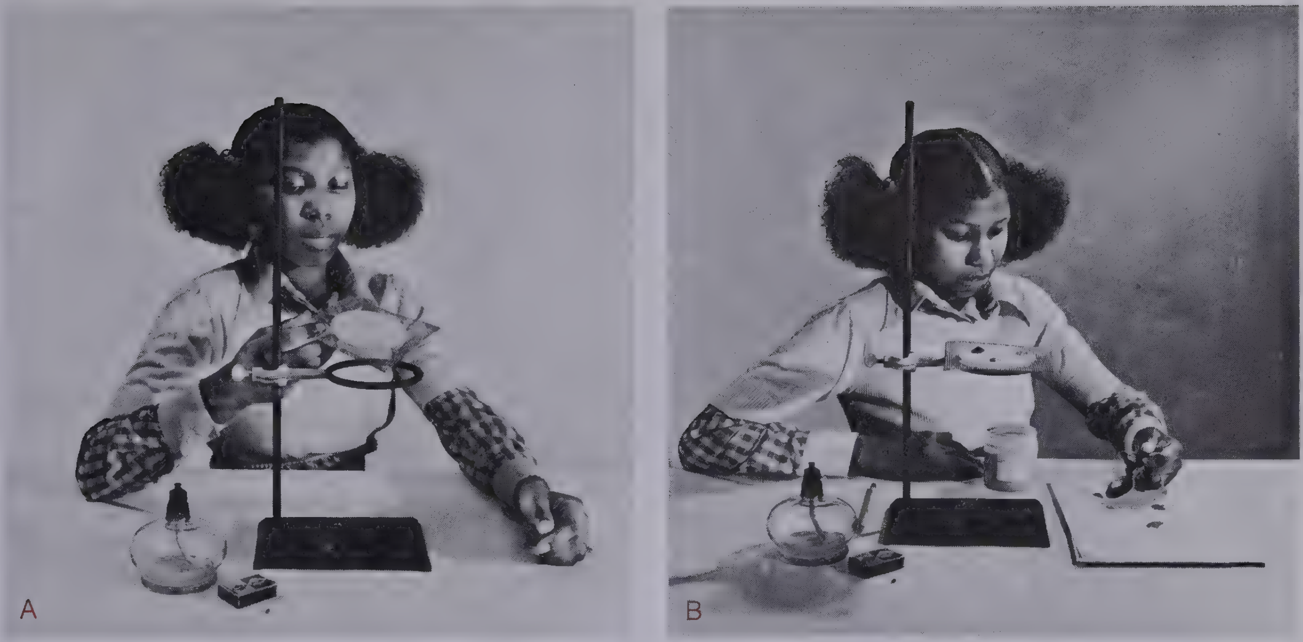


Figure 14-4 (*A*) *The setup for heating powdered metals.* (*B*) *Arrange the metals on the paper in the same way as on the asbestos.*

the spoon. Repeat the steps with zinc and then with iron. Figure 14-4B shows you where to put the zinc and iron. Label the zinc Zn and the iron Fe.

Get some water in a paper cup. Add salt to the water and stir. Keep adding salt and stirring until some salt remains on the bottom of the cup. With a dropper, add one or two drops of salt water to each metal on the asbestos.

Place a lit burner under the asbestos at the center of the triangle of metals. Heat the metals for 12 minutes. Add one drop of salt water to each metal every minute. Be careful not to burn yourself.

Allow the metals to cool. Use a wood splint to brush each metal from the asbestos onto the sheet of paper. Put the aluminum you heated next to the unheated aluminum, the heated zinc beside the unheated zinc. Compare the heated and unheated metals. What do you observe? ★

In this experiment, you did not do anything to change the spoonfuls of metal on the sheet of paper. You used them to compare with the metals that you heated. If you had tried comparing them from memory, you might have forgotten exactly how they looked. You also needed to see if the same changes could take place by just leaving the metals on the paper for the same amount of time. The part of the experiment that you do not change is called the **control.** The unheated metals acted as a control.

You have seen tools, toys, and other objects that have rusted. **Rust** is a compound of iron and oxygen. (Actually it is a mixture of two different iron compounds.) Compounds of metals and oxygen are called **oxides.** Water speeds up the formation of rust. Salt water speeds it up even more. What does the heat do? Where does the oxygen come from?

Materials
iron nails, aluminum nails, galvanized nails, stand, wire gauze, burner, paper cup, plastic spoon, dropper, salt water

★ Look carefully at all the nails. Use a whole sheet of paper to make a copy of the chart in Figure 14-5. Place an iron nail, an aluminum nail, and a galvanized nail in their spaces on the paper. Polish an iron nail, an aluminum nail, and a galvanized nail with sandpaper until they are shiny. Place the polished nails on the paper.

Figure 14-5 *Make a full-page copy of this chart.*

	Iron nails	**Aluminum nails**	**Galvanized nails**
Unchanged nails			
Polished nails			
Polished and heated nails			

Set up a stand with a wire gauze. Polish one of each type of nail. Put them on the asbestos (Figure 14-6). Place a lit burner under the points of the nails. Then put some salt water on the points of the nails and heat them for 10 minutes. Add a few drops of salt water to the nails every minute.

Heat the nails 5 more minutes. Put several drops of tap water on the points of the nails every minute. Allow the nails to cool. Then put them in their spaces on your paper. Compare the points of all the nails. Which nails have a coat or covering on them? Are the coats different from each other? What was the control in this experiment? ★

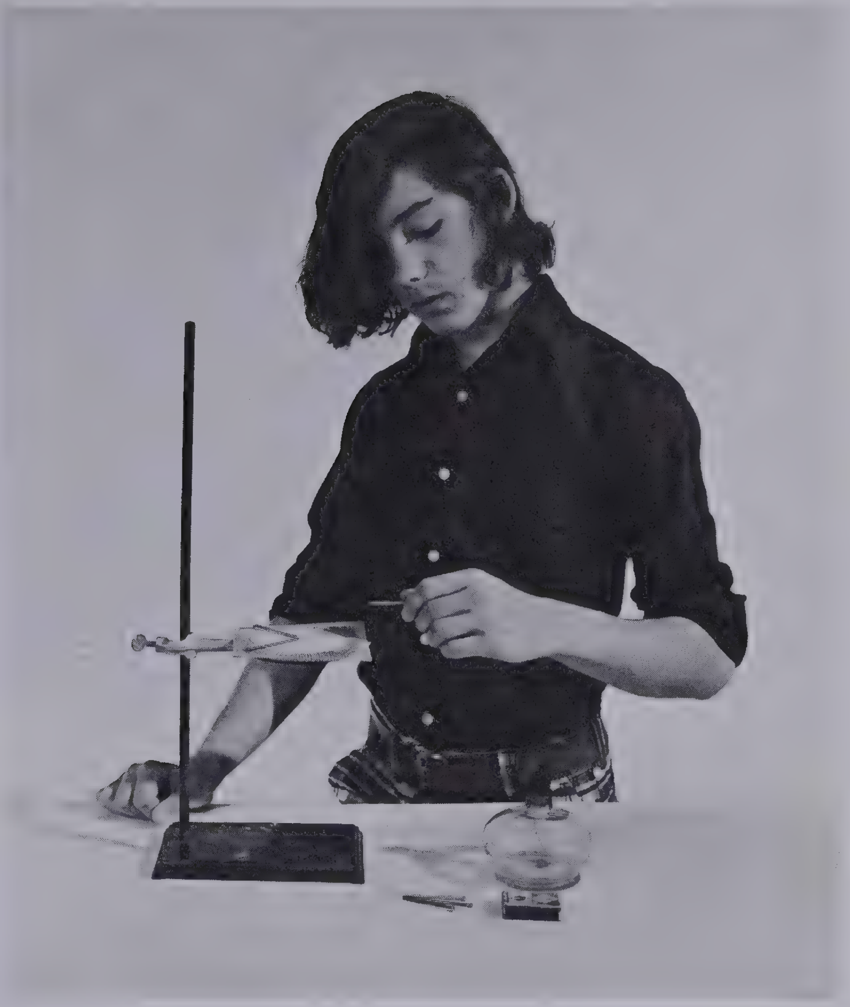


Figure 14-6 *Place the three nails on the asbestos as shown.*

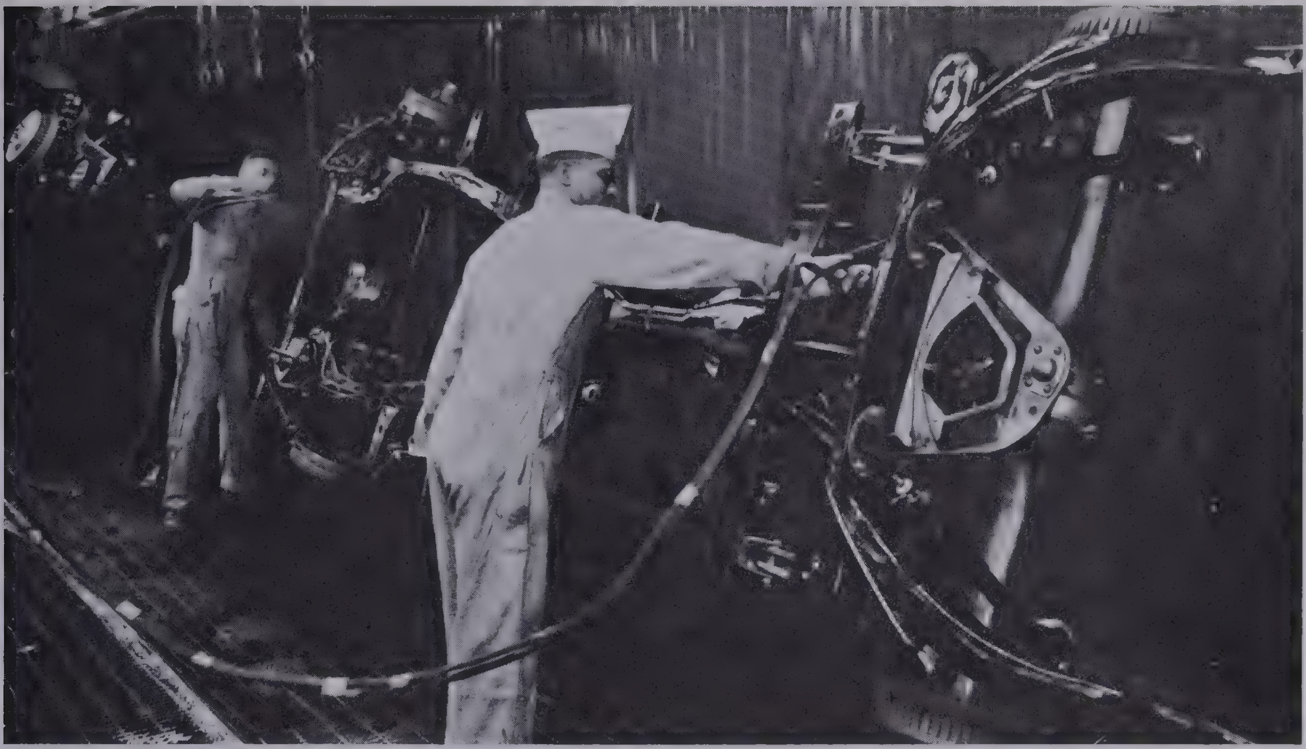
When iron rusts, a coat that falls off is formed. The material under the coat is not protected. More oxygen can join with the iron under the coat, so iron oxide (rust) continues to form.

When oxygen joins with aluminum, aluminum oxide is formed. When oxygen joins with zinc, zinc oxide is formed. Coats of aluminum oxide and zinc oxide are different from rust. They do not fall off. The oxides of aluminum and zinc protect the metals under them. They keep the oxygen away from the metal.

Iron can be protected by coating it with zinc. When iron or steel is coated with zinc, it is **galvanized.** How does galvanizing protect iron? Are there other ways that metals can be protected?

Rust does not flake off this new alloy of steel. The rust coating sticks to the metal and protects it the same way a coat of paint would.

The roof of this building is made of copper. The oxide coating has turned the roof bluish-green.



RUST PREVENTER

Nobody likes rust, but it makes jobs for a lot of people. Many of the things we use—from oil refineries and bridges to water pipes and bicycles—are made of iron and steel. They all have to be protected from rust.

Automobiles are made largely of steel, although you don't see most of it. Many parts of a car have to be covered with a protective coating. The body is given several layers of very hard paint. The frame gets special paint to protect it from water and salt. Radiator grilles, door handles, and other parts are usually covered with chrome. (Chromium is a metal that forms oxides much more slowly than iron or steel.) Roofs are sometimes covered with vinyl.

Some of the people who put on these rust-prevention coatings work in the plants where automobiles are made. Others work in repair shops all over the country. Most of them are high school or vocational school graduates who enjoy working with their hands. They learn their jobs as apprentices.

14-6 Active metals

Materials
magnesium ribbon, sandpaper, tweezers, burner

★ Magnesium is a metal with the symbol Mg. Does sandpaper give magnesium a shine? Magnesium can burn. **Caution: Do not look at the burning ribbon for long. The bright light can harm your eyes.** ★

When magnesium burns, it joins with oxygen. A compound called magnesium oxide is formed. When a substance reacts easily with others it is called **active.** When you placed strips of Al, Cu, Zn, Fe, and Pb in a burner flame, did they burn? Which is more active, magnesium or iron?

Sodium, Na, is a very active metal. It is one of the most active elements. Sodium is so active that it is dangerous. Look at Figure 14-7. What are some of sodium's properties? Sodium is so active that it must not come in contact with air. If sodium comes in contact with air, it reacts violently. What compound is formed?

Figure 14-7 *How's this for action? Sodium reacts violently with water and air.*

Did You Get the Point?

Most metals are shiny solids.

Metals conduct electricity and heat.

Metals react with oxygen to form compounds called oxides.

Some metals are more active than others.

What Have You Learned?

1. Name the elements whose symbols are given: Your parents may have a frying pan made of Fe. A water bucket may be coated with Zn. A foil that is often used in your home is made of Al. Some tea kettles are made of Cu.

2. What property of magnesium makes it useful for flash bulbs?

Non-metals

14-7 The halogens

There are many elements that are not metals. These elements are called non-metals. Metals are easy to describe because they share many properties. However, one non-metal can be very different from another. For example, sulfur is a yellow solid but oxygen is a colorless gas. For the moment, **non-metals** will be defined as those elements that do not have the properties of metals.

One group of non-metals is called the halogens. See Figure 14-8. The halogens are active elements. These elements are not found alone in nature. They are found only in compounds with other elements. For example, chlorine is often combined with the active metal sodium in a compound called sodium chloride. Sodium chloride is table salt.

Figure 14-8 *The halogens.*

Name	Symbol	Appearance at room temperature
Fluorine	F	pale yellow gas
Chlorine	Cl	greenish-yellow gas
Bromine	Br	reddish-brown liquid
Iodine	I	gray solid

When the halogens are not combined in a compound, they are poisonous. Because they are poisonous and very active, the halogens are dangerous to work with. The only halogen you will handle in class is the least active one, iodine.

Figure 14-9 *A person who is having trouble breathing may be given extra oxygen through an oxygen mask.*

14-8 Oxygen

Materials
test tube, rack, beaker, hydrogen peroxide, plastic spoon, manganese dioxide, paper, burner, wood splints

People need oxygen to stay alive (Figure 14-9).

★ Fill a test tube $\frac{1}{4}$ full with hydrogen peroxide. This is a compound of hydrogen and oxygen. Fold a piece of paper in half. Place $\frac{1}{2}$ spoonful of manganese dioxide on the paper. Add the manganese dioxide to the hydrogen peroxide as shown in Figure 14-10. Immediately cover the mouth of the test tube. The gas called oxygen (O) will form in the test tube. Half the class will test the gas with a burning splint. Half the class will use a glowing splint. What happens to the burning splint? What happens to the glowing splint? Does the oxygen gas itself burn? Does oxygen help other substances burn? ★

The manganese dioxide in this activity was not really necessary. Hydrogen peroxide can break down to form oxygen without the manganese dioxide. But the reaction would be much slower. A substance that is added to a reaction to speed it up is called a **catalyst.** Manganese dioxide is a catalyst in the preparation of oxygen from hydrogen peroxide. You have used catalysts before. In which activities did you use catalysts?

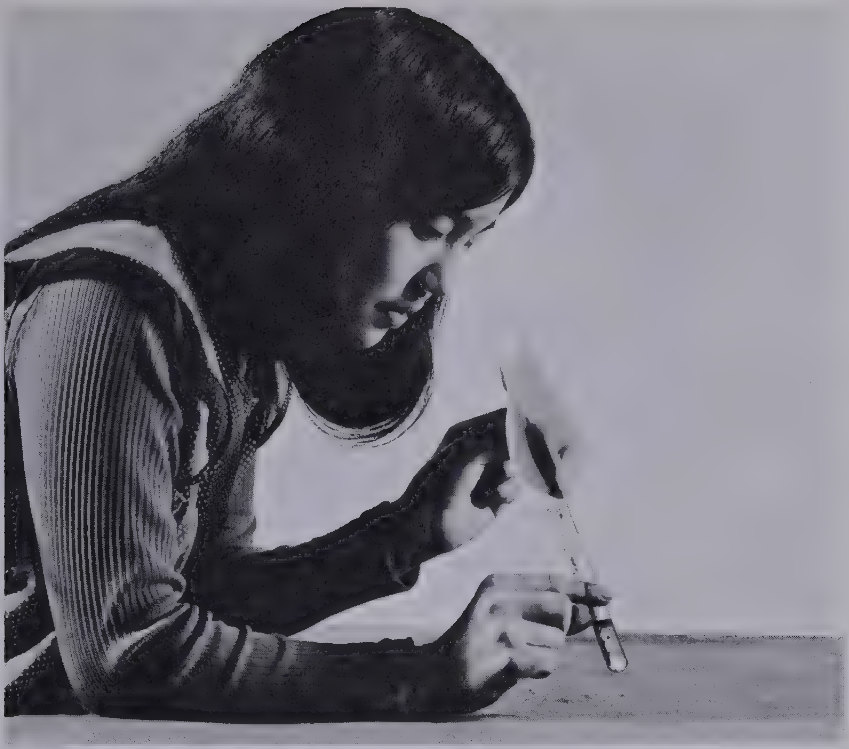


Figure 14-10 *How to pour a powder into a test tube.*

14-9 Hydrogen

Materials
test tubes, rack, vinegar, beaker or graduate, burner, magnesium ribbon, wood splints

★ Pour vinegar into a test tube until it is ¼ full. Drop a piece of magnesium ribbon into the test tube. Hold your thumb over the opening of the test tube. Half the class will test the gas that forms with a burning splint. Do not insert the burning splint in the test tube. Just bring it near the opening. Half the class will use a glowing splint. Does the burning splint burn more brightly? Does the glowing splint burst into flame? What happens to the gas in the test tube? ★

The gas in the test tube is hydrogen. The symbol for hydrogen is H. What do you think would happen if you brought a flame near a mixture of hydrogen and oxygen in a test tube? (Do not try this. Just think about it.)

14-10 Nitrogen

Materials
large beaker, water, test tube, iron filings, salt, clamp, ringstand, burner, wood splint

★ Fill a large beaker with water. Fill a test tube with water. Pour the water out of the test tube into the sink. Sprinkle ¼ teaspoon of iron filings into the wet test tube.

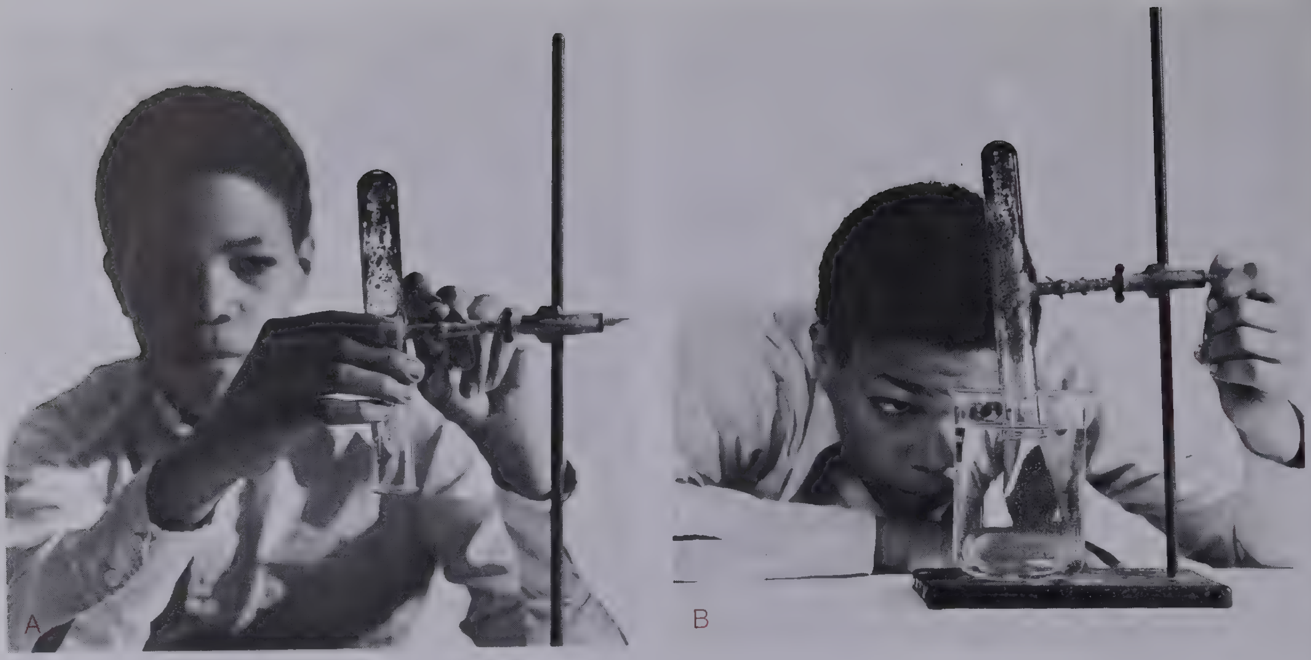


Figure 14-11

The iron filings will stick to the sides of the test tube. Sprinkle $\frac{1}{4}$ teaspoon of salt into the same test tube. The salt will act as a catalyst.

Clamp the test tube upside down on the ringstand as shown in Figure 14-11A. Place the beaker of water under the test tube. Move the clamp until the mouth of the test tube is just under the surface of the water. See Figure 14-11B.

Near the end of class, look at the test tube. How high did the water rise into the test tube? Has the iron changed? What new substance is in the test tube? Stopper the test tube and turn it right side up. Half the class should test the gas with a glowing splint, half with a burning splint. How much gas is present? Does the gas in the test tube burn? Does it help other substances to burn? Is the gas oxygen? Is it hydrogen? ★

Air is a mixture of several gases. About 79% of the air is nitrogen. About 20% is oxygen. Small amounts of many other gases including carbon dioxide and water vapor are also found in air.

What gas must have been left in your test tube? What happened to the oxygen in the air? Why did the water rise in the test tube?

The halogens are a group of active, poisonous non-metals.

Oxygen helps other things burn, but it does not burn.

Hydrogen burns but it does not help other things burn.

Nitrogen neither burns nor helps other things burn.

Oxygen, hydrogen, and nitrogen are non-metals.

A spark set off the explosion of the Hindenburg. What gas do you think filled the dirigible?

What Have You Learned?

1. Is air an element, a compound, or a mixture?

2. What would happen if there were large amounts of hydrogen in the air?

3. What would happen if the air were 20% nitrogen and 80% oxygen?

4. What two elements is water made of?

SKULLDUGGERY

1. Your teacher will give you a copy of the puzzle (Figure 14-12). Do not write in the book. Read each definition and write the words in the puzzle. The letters in the vertical box will spell out a special message.

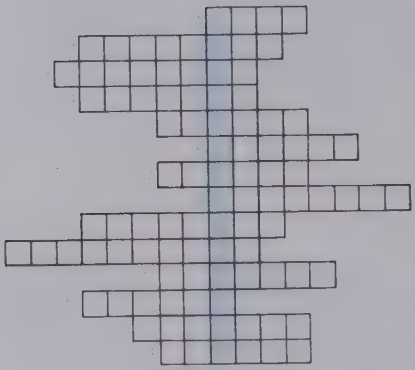


Figure 14-12

Definitions

1. Compound of iron and oxygen
2. Substance that can be broken down
3. Substance that speeds up a reaction
4. Mass divided by volume
5. Compounds of metals and oxygen
6. Something that stands for an object or idea
7. Shiny elements
8. A non-metal that burns
9. Group of active non-metals
10. Iron that is coated with zinc
11. The part of an experiment that does not change
12. A substance that reacts easily with others is ________
13. Substance that cannot be broken down into different substances
14. An element that helps other things burn

2. Some pots and pans are made of aluminum. Others are made of stainless steel or cast iron. What properties of each metal make it useful for cooking? Go to a store or look in a mail-order catalog to find the prices of each type. Is the most expensive the best?

Some pots have copper bottoms that darken when heated. For best results in cooking, should these be cleaned to make them shiny?

3. Chlorine is used in water purification plants and in private swimming pools. You can smell chlorine in a pool and sometimes it makes your eyes smart. Can you smell it in your drinking water? Call or write swimming pool supply companies and your town's Public Works Department to find out how much chlorine is added to the water in each case.

FOR FURTHER READING

Asimov, Isaac. *The Search for the Elements.* New York: Fawcett World Library, 1971. History and development of chemistry.

Asimov, Isaac. *The World of Nitrogen,* rev. ed. New York: Abelard-Schuman Ltd.; 1962. Discusses an important element in the chemical composition of living things.

Brooks, Anita. *The Picture Book of Metals.* New York: The John Day Company, Inc.; 1972. History of metals other than iron and their influence on civilizations.

Chase, Sarah Hannum. *First Book of Diamonds.* New York: Franklin Watts, Inc., 1971. Legendary and historical stories. Also modern mining and cutting techniques.

WHAT'S NEXT?

In books and movies, scientists often appear as absent-minded professors who never know what they are doing or where they are going, or mad geniuses who invent monsters, deathrays, and anti-gravity machines. But real scientists aren't any funnier or crazier than other people. They can't depend on lucky accidents and they can't do the impossible. They depend on careful observation, on accurate recording, on clear thinking, and on experiments to check if their ideas work or not. In the next chapter, you will see some of the ways in which real chemists go about their business.

What Is It?

If you were asked to pick out one particular person from a crowd of 100,000, you probably couldn't do it. But chemists are doing something like that every day. They can pick out and name very tiny amounts of a substance. This is useful in such different fields as medical research, police work, and sports.

At every race track, a chemist checks the racehorses to make sure that none of them have been given drugs to speed them up or slow them down. Even a tiny trace of any drug can be spotted in the horse's saliva.

Athletes are also checked for drugs. And this had unfortunate results for one of the United States Swimming Team at the 1972 Olympic games. Rick DeMont had won the 400 meter free-style final. But a check of his urine showed traces of a drug—just twelve parts in a million, but it was there.

The officials should have known about the drug. Rick had been using it for years to control his asthma. He had told the American team officials about this, but they did not pass on the information to the Olympic committee. Unfortunately, the drug could be used as an ''upper,'' to give a swimmer more speed and energy, and the Olympic rules are strict. Rick was disqualified from the games.

Identifying Substances

15-1 Melting points

In Section 13-5 you had to identify an unknown metal. You knew that the metal was either copper, aluminum, or lead. The pieces of metal were disguised to keep you from recognizing them by just looking. The densities of copper (8.9 g/cm^3), aluminum (2.7 g/cm^3), and lead (11.3 g/cm^3) are very different. Your measurements of mass and volume did not have to be extremely accurate. You probably had no trouble identifying your unknown metal.

There are books called handbooks where you can find the properties of substances. If you have an unknown, you first measure some of its properties. Then you try to identify it by checking the lists in a handbook. Sometimes you have two unknowns and you simply want to know if they are the same or different. This time you don't have to use a handbook. You just compare the substances to each other.

Density is an important property of matter. A drop of pure water and a liter of pure water have the same density. But is density alone enough to identify a substance?

Materials
test tubes with unknowns, graduate, coat hanger balance

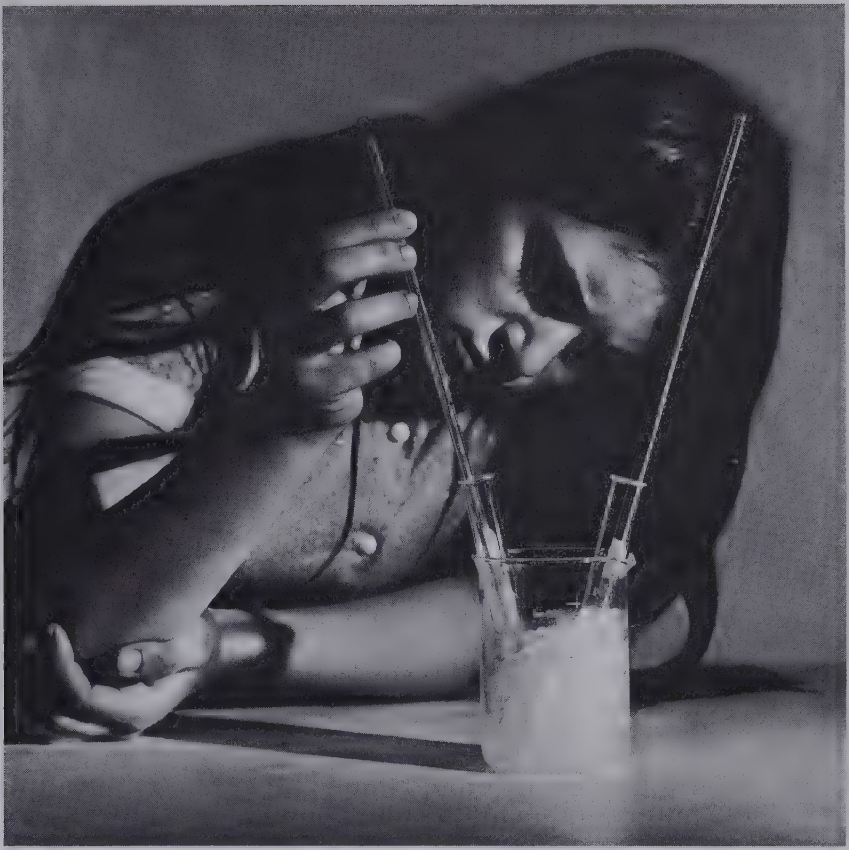
★ Label your test tubes so that you can tell them apart. Find and record the density of each liquid. Are your two unknowns different or the same? Can you be sure? ★

You cannot be sure whether you have one or two liquids from density alone. You need to know more of the unknowns' properties. One important property of a liquid is its freezing point. A liquid changes to a solid at its **freezing point.** The freezing point for water is 0°C. This temperature is also called the melting point of water. At the **melting point,** a solid changes to a liquid. Every pure substance has a constant freezing point. See if your liquids have the same freezing point.

Materials
test tubes of unknown liquids, beaker, crushed ice, 2 thermometers, clock

★ Fill a beaker halfway with crushed ice. Measure the temperature of the crushed ice and write it down. Put a thermometer in each test tube and measure the temperatures of the liquids. Set the test tubes in the crushed ice as in Figure 15-1. Measure the temperatures of the liquids every 2 minutes for 12 minutes. What happens to the liq-

Figure 15-1 *Testing for the freezing points of two liquids. How can you find the melting points for these unknowns?*



uids? Do both liquids act the same? What is the lowest temperature you get for each liquid? Are your two liquids different or the same?

Caution: Do not try to remove a thermometer from a frozen material. Take the test tube out of the crushed ice and let the solid melt. Then you can safely remove the thermometer and clean it. ★

Some of the test tubes contained benzene and some contained toluene. The density of benzene is 0.88 g/cm^3. The density of toluene is 0.87 g/cm^3. Your measurements of mass and volume are not accurate enough to tell benzene and toluene apart. The densities are too similar. But the freezing points of benzene (5.5°C) and toluene (−95°C) are very far apart. You can use the freezing points to tell them apart. Why didn't the toluene freeze when you put the test tube in crushed ice?

Compare your results to those of the rest of the class. Did everyone find that benzene freezes at the same tempera-

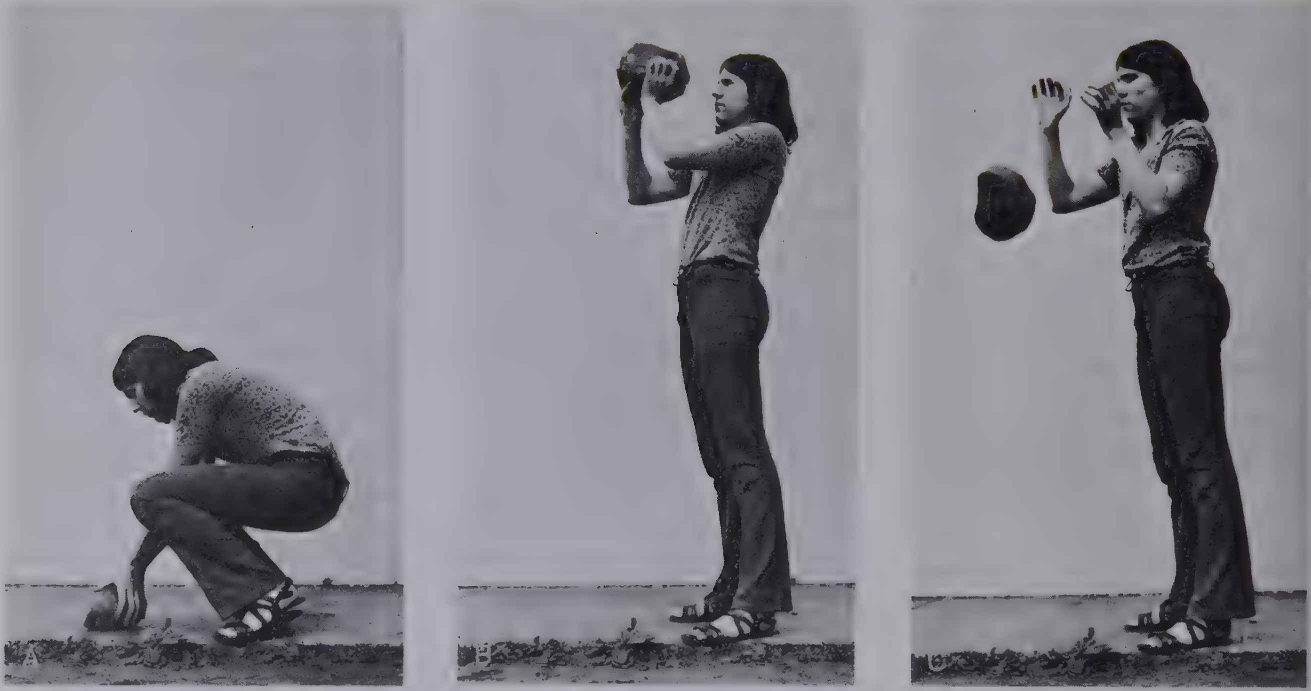


Figure 15-2 (*A*) *The rock is attracted to the earth. The boy uses energy to lift it.* (*B*) *The energy he used is stored in the rock. The rock has potential energy.* (*C*) *If he drops the rock, the potential energy is changed to kinetic energy.*

ture? What was the lowest freezing point measured? What was the highest freezing point measured? If benzene always freezes at the same temperature, why were different freezing points measured?

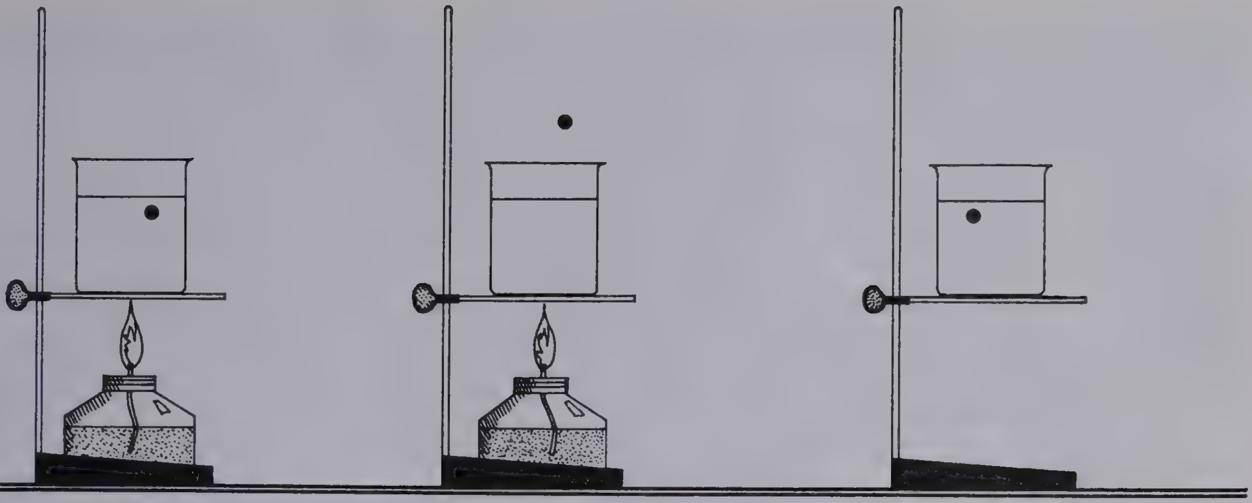
15-2 Boiling points

Another property that can be used to identify a substance is its boiling point.

Materials
container, thermometer, burner, stand, clock, stirring rod

Put water in your container. The water should be 8 to 10 cm deep. Stir well and read the temperature. Now begin to heat the water. After two minutes, stir and take the temperature again. Repeat every two minutes. After the water starts to boil, take the temperature at least four times. Write B after the temperature if the water is boiling.

During your experiment, heat energy went into the water. This made the particles move faster. The average kinetic



Particles in a liquid are attracted to each other. The temperature of this water is 100°C. The flame is giving energy to the particles.

A particle uses the energy from the flame and moves away from the particles that attract it. It stores the energy as potential energy. Now it is a gas particle.

If the particle gives away its potential energy, it can return to the liquid.

Figure 15-3

energy was greater, so the temperature was higher. But when the water boiled, the temperature stayed the same. The burner kept giving energy to the water. Why didn't the temperature go up?

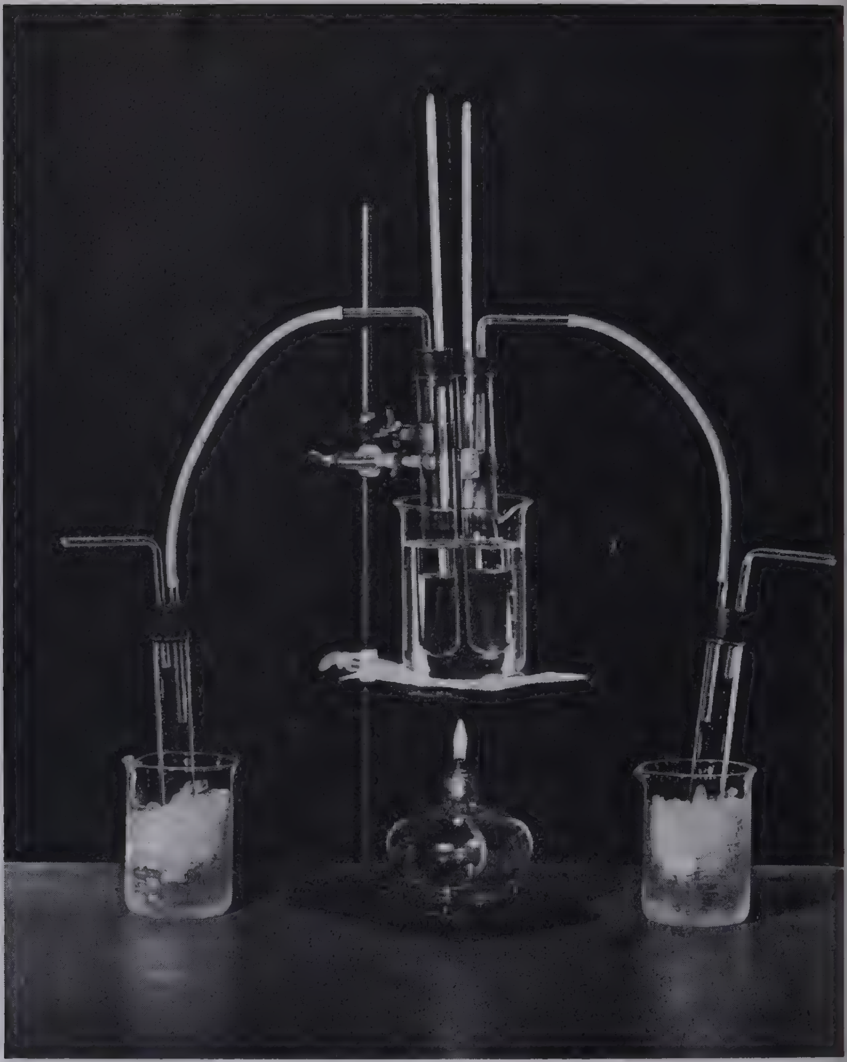
Perhaps you noticed something else while the water was boiling. Some of it disappeared. If you boil water long enough, all of it will disappear. **Boiling** changes a liquid into a gas. The **boiling point** is the temperature at which the liquid boils.

Particles in a liquid attract each other. It takes energy to pull them apart. Pulling the particles apart is like lifting a weight. See Figure 15-2 for a review of potential and kinetic energy. Then study Figure 15-3. Notice that the same energy changes happen with particles.

If you spill boiling water on your skin, it hurts. If you put your hand in the steam from a kettle, it would hurt much more. Why? The pictures in Figure 15-3 should help you find the answer.

Pure water boils at 100°C. Other pure substances boil at different temperatures.

Figure 15-4 *Measuring the boiling points of toluene and benzene.*



Materials
stand, clamps, wire gauze, 3 beakers, 2 flasks, 4 large test tubes, 4 2-hole rubber stoppers, glass tubing, rubber tubing, thermometers, burner, water, crushed ice, toluene, benzene

★ Your teacher will use the setup shown in Figure 15-4 to try to measure the boiling points of toluene and benzene. This is the setup that is often used to measure the boiling points of substances that form poisonous or explosive vapors. Why is the setup useful in these cases? What is the purpose of the crushed ice and water?

Begin to heat the water. As the water is heated, write down the temperatures of benzene and toluene every 2 minutes for 12 minutes. Can you find the boiling point for both liquids? If you can't, try to explain why. Can you tell the difference between benzene and toluene by their boiling points? ★

ANALYTICAL CHEMIST

Sometimes the things we use to make our lives easier or more comfortable end up doing more harm than good. Phosphate detergents wash clothes cleaner, but they pollute rivers and streams. DDT kills insect pests that destroy crops, but it also kills wildlife. When we find this happening, we have to start looking for other, safer, ways to do the same job. Discovering what went wrong and how to do better is the work of the analytical chemist.

Analytical chemists research the structure and properties of many different substances. They identify unknown elements and compounds. They also work out better methods to test the quality of new products, to make sure that the products do their jobs without harmful effects. Analytical chemists work for industry, research institutes, universities, and the government.

To become an analytical chemist, you must have at least a bachelor's degree with a major in chemistry from a 4-year college. You must have a lot of curiosity and imagination as well as a good deal of patience.

15-3 Solubility

You will not be able to identify every substance by its melting point, boiling point, and density. For instance, common table salt melts at 801°C and boils at 1413°C. Your burner flames are not hot enough to melt or boil salt. You will need to know other properties before you can identify unknown substances.

When you had a mixture of salt and sand, you were able to separate it. Salt dissolves in water but sand does not. What are some other substances that dissolve in water? What substances do not dissolve in water?

When you dissolve a substance in a liquid, you make a special kind of mixture called a **solution.** Your teacher has two solids. They both have a density of 4.5 g/cm^3. Can you make solutions of these solids with water?

What if you have three solids that all dissolve in water? Can you tell them apart?

Materials
unknown solid, small beaker, graduate, plastic spoon, water, coat hanger balance, stirring rod, burner, stand, wire gauze, thermometer, standard masses

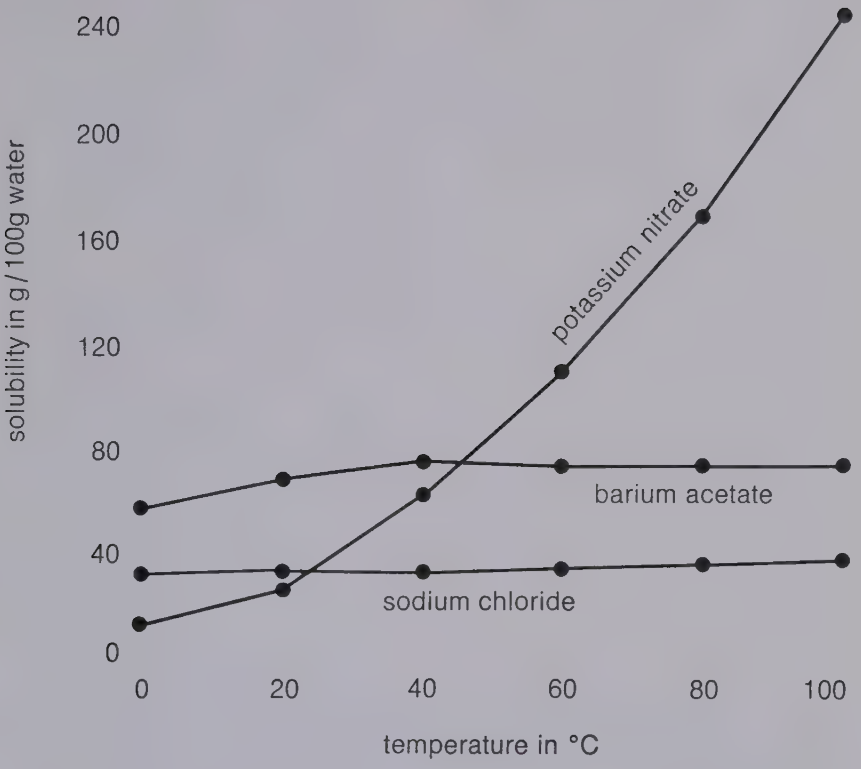
Put exactly 50 ml of cold water in a beaker. Write down the temperature. Using your balance, measure exactly 50 g of your unknown. Use your spoon to add a small amount of solid to the water. Stir the solution with your stirring rod. If all the solid dissolves, add some more. Keep adding small amounts until some solid remains at the bottom of the beaker. Find the mass of the solid that you did not dissolve. Subtract this mass from 50 g to find the total amount of solid that you added.

Heat your solution to 40°C. Does the solid on the bottom of the beaker dissolve in the warm water? If it does, keep adding small amounts until no more will dissolve. Again, find the mass of the leftover solid and subtract the result from 50 g to find the total amount dissolved.

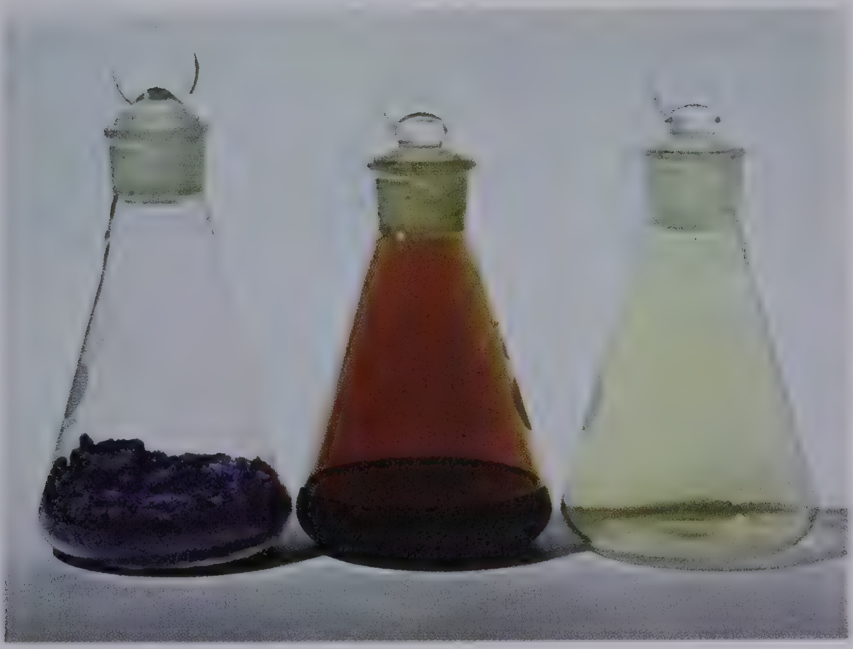
You have been measuring the **solubility** of your solid in water. Solubility is usually reported in grams of solid that dissolve in 100 ml of liquid. How much water did you start with? What number must you multiply your totals by to compare them to standard solubilities? Use the graphs in Figure 15-5 to decide which solid you had. Did more of your solid dissolve in warm water than in cold water?

Not all solutions are made with water. Not all solutions contain a solid and a liquid. Two liquids can also make a solution.

Figure 15-5 *Solubility of three compounds at various temperatures.*



Three halogens: iodine (solid and vapor), bromine (liquid and vapor), and chlorine (gas).



Materials
test tubes, rack, stoppers, graduate, water, benzene, alcohol

★ Pour 10 ml of water into one test tube and 10 ml of alcohol into a second test tube. Use masking tape or a marking pen to label the test tubes. Add 5 ml of benzene to each test tube. Stopper the test tubes and shake well. Then place them in the rack and let them stand for a minute.

Is benzene soluble in water? Is benzene soluble in alcohol? Is alcohol soluble in water? When the liquids were not soluble, layers formed. What property of matter helps you decide which one forms the top layer? ★

15-4 Flame tests

Look at the compounds in the bottles on the demonstration table. Each of the compounds contains the same familiar element. Can you tell which element it is by looking at the compounds? The name of each compound is on the bottom of the bottle. If the same element was used to form each compound, why are the compounds different? Why don't the compounds look like the element?

When you know the name of a compound, you can tell which elements formed it. But there is a way to identify some elements in their compounds without knowing the name of the compound. You can test the compounds with a flame.

Materials
burners, platinum or chromel wires, cobalt glass squares, solid samples and solutions of copper, calcium, potassium, sodium, barium, and strontium compounds

★ Make a list of compounds. Dip your wire into the solution and then into the solid compound. Hold the wire in the burner flame (Figure 15-6). Write the color of the

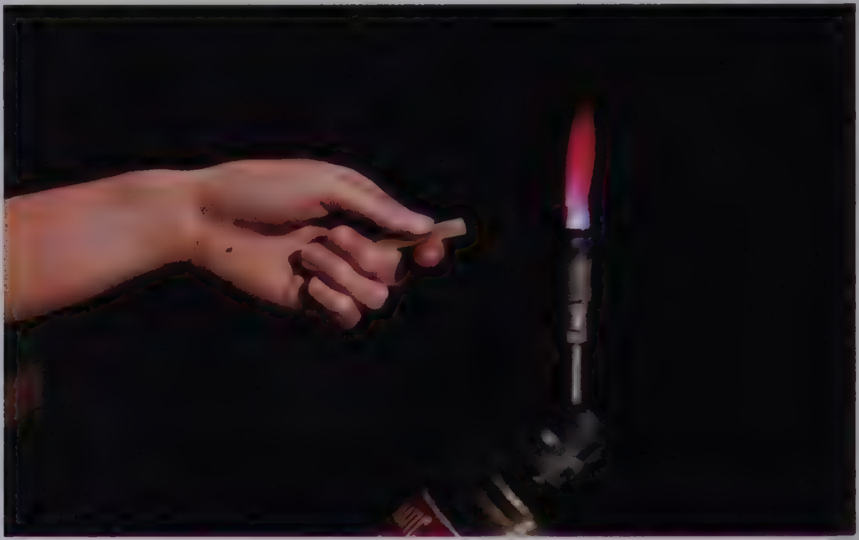


Figure 15-6 *A flame test.*

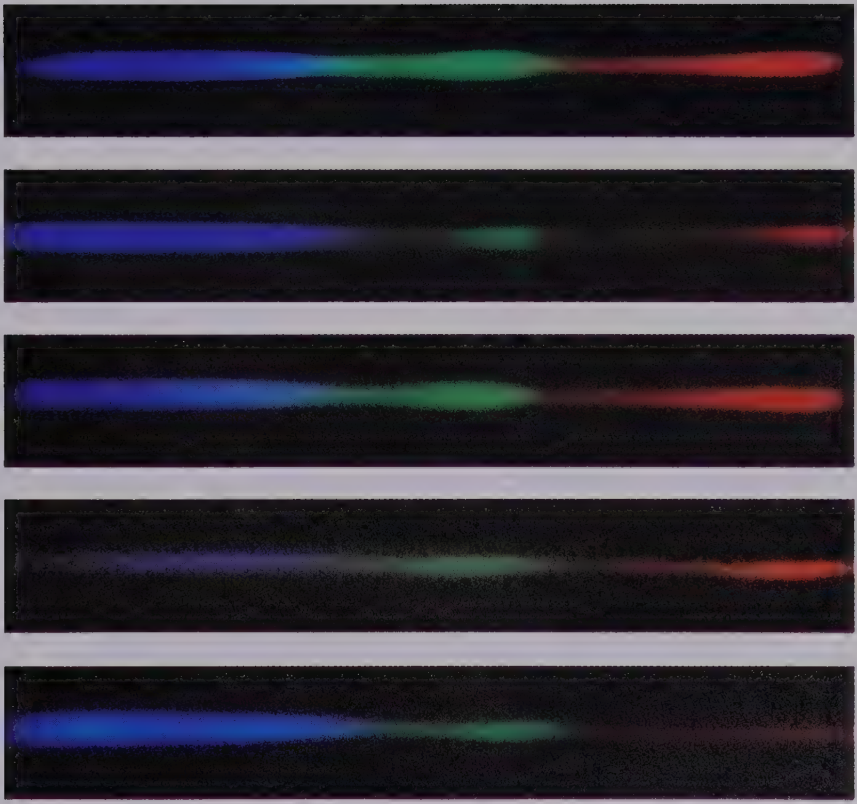
flame next to the compound in your list. When you test a potassium compound, look at the flame through a cobalt glass square. ★

Do copper chloride and copper nitrate give the same color flame? Do copper chloride and sodium chloride give the same color flame? Which element in each compound produces the color? Which elements give you colored flames, metals or non-metals?

Materials
spectroscope

★ Look at a burner flame through a spectroscope. Now look at the flame produced by one of your compounds. The lines you see are a bright line spectrum. Look at the spectrum for each of the compounds. Are all the bright line spectra the same? ★

Each element produces a different bright line spectrum. Your burner flame is not hot enough to produce the spectra of all elements. This is why you do not see the lines for the non-metals in your compounds. The flame is not even hot enough to produce all the lines for the spectra of metals. When sodium is heated in a very hot flame, more than one line can be seen.



Spectra of five stars. From the spectrum of a star, astronomers can tell how hot the star is and what elements are in it.

15-5 Testing for iodine

Materials
3 test tubes, rack, iodine, stoppers, water, alcohol, benzene, graduate

You will be given three test tubes that contain small pieces of iodine. **Caution: Do not breathe in the vapors of iodine. They are poisonous.** Add 10 ml of water to the first test tube, 10 ml of alcohol to the second, and 10 ml of benzene to the third. Label each test tube. Stopper and shake them. What color is the water? What color is the alcohol? What color is the benzene? Is iodine soluble in water? in alcohol? in benzene?

Chemists do not know of any other substance that gives this color solution with benzene. You can test for iodine by dissolving it in benzene. A **test** is a way to check whether a substance is present in a material or not.

The test for an element works whether the element is by itself or in a mixture. The properties of an element do not change when it forms a mixture. The properties of an element do change when it forms a compound. If you want to use benzene to test for iodine in a compound, you must first change the compound and set the iodine free.

Materials
salt, test tube, graduate, water, benzene, chlorine water, dropper

Put one teaspoon of salt in a test tube. Can you tell by looking whether you have iodine in your salt? Add 10 ml of water. Stopper and shake the test tube. Some salt will remain at the bottom of the tube.

Add 5 ml of benzene to the salt water. Shake the test tube again. Does the benzene change color? Add 3 ml of chlorine water to your mixture and shake it once more. Is the benzene layer light purple or pink? Did you have iodized salt? How could you show that the iodine is not part of the chlorine water?

A compound in chlorine water contains the element chlorine. Chlorine can take the place of iodine in a compound. Iodine is set free as an element. There is only a small amount of iodine compound in iodized salt.

Each pure substance boils at a fixed temperature and freezes at a fixed temperature.

You need to know more than one property of a substance to identify it.

Solubility is the greatest amount of solid that dissolves in 100 ml of a liquid at a given temperature. A change in temperature causes a change in solubility.

The colors of flames can be used to identify some elements.

Each element has a different bright line spectrum.

A purple solution with benzene is a test for iodine.

1. Use the information in Figure 15-7 to answer these questions: (a) Which property would you use to tell methyl acetate from acetone? (b) If you had both wood alcohol and acetone, which property would you use to tell them apart? (c) How would you tell the difference between wood alcohol and grain alcohol?

Figure 15-7 *Table for Question 1.*

Substance	Density (g/cm^3)	Melting Point (°C)	Boiling Point (°C)
wood alcohol (methanol)	0.79	−98	64.7
grain alcohol (ethanol)	0.79	−117	78.5
methyl acetate	0.93	−98	57
acetone	0.79	−95	57

2. Look at Figure 15-8. Two of the elements whose spectra are shown in A, B, C, and D were heated together. When the light was looked at with a spectroscope, the spectrum in E was seen. What two elements were heated together?

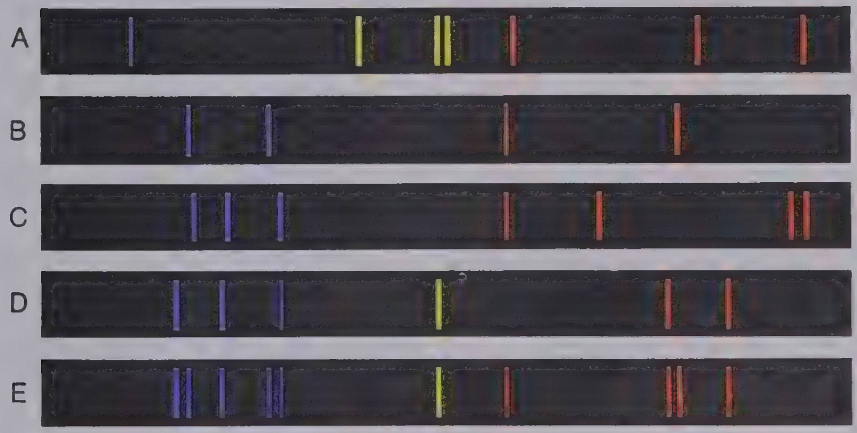


Figure 15-8 *Use this to answer Question 2.*

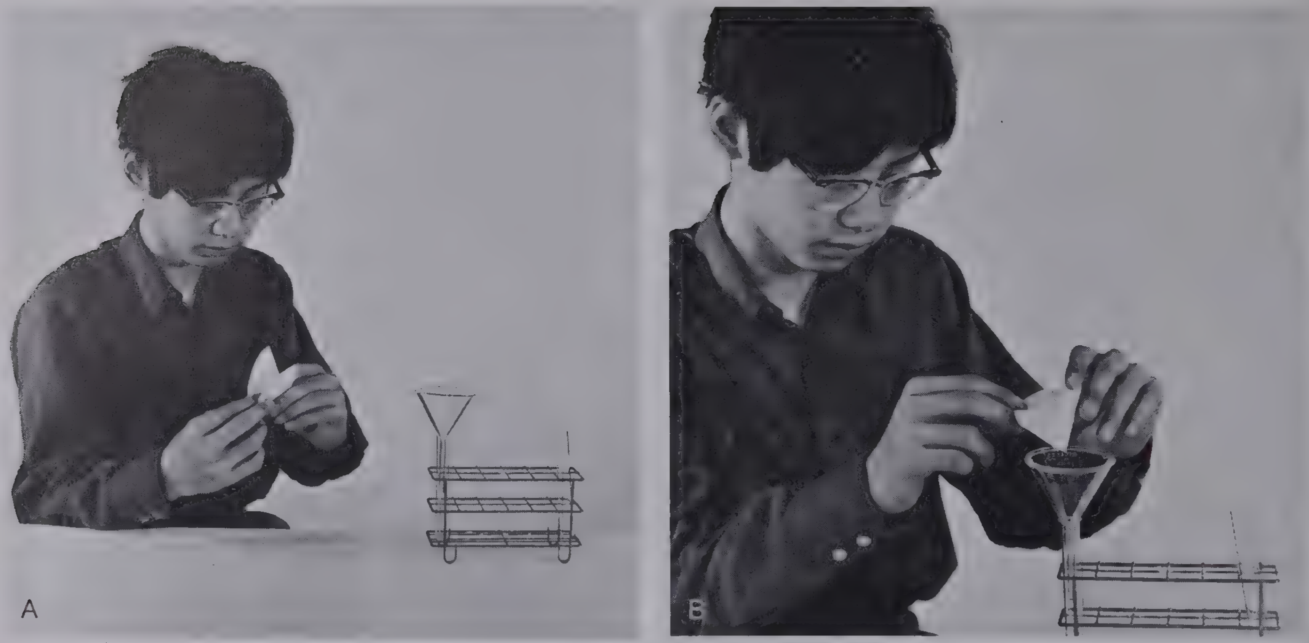


Figure 15-9 (*A*) *Folding the filter paper.* (*B*) *Why do you think the funnel should be wet?*

Separating Mixtures

15-6 Using solubility

The set of properties of each substance in a mixture do not change. If two substances differ widely in one property, you can use the difference to separate the substances. For example, you used water to separate salt from sand. Salt dissolves in water but sand does not. This difference in the property of solubility made it easy to separate the two substances.

Materials
black powder, filter paper, funnel, water, 5 test tubes, rack, stirring rod, graduate, beaker

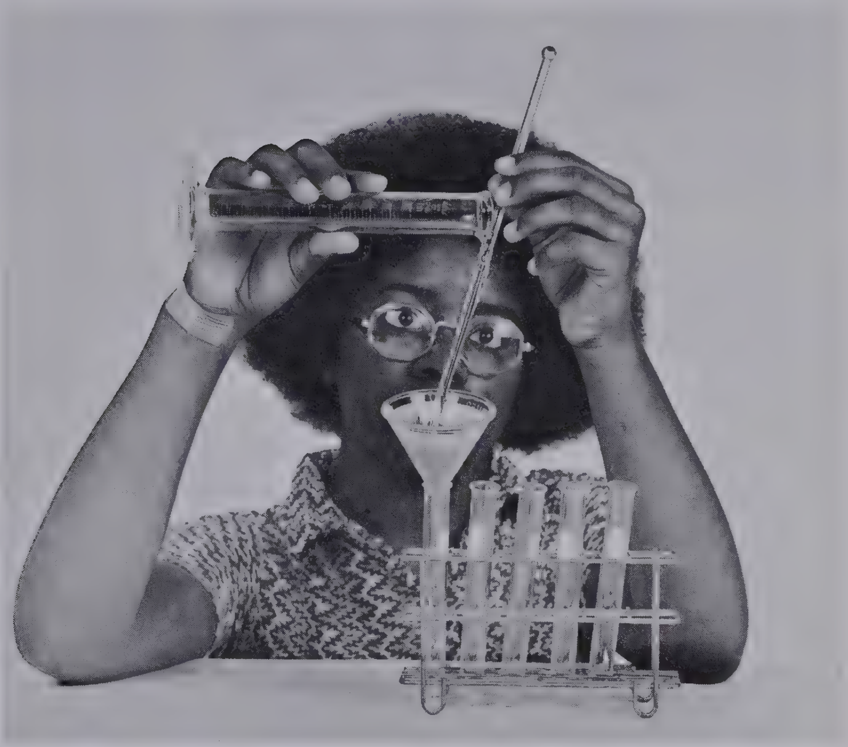
★ Look at your black powder. Do not touch it. Can you tell whether the black material is a substance or a mixture?

Fold a piece of filter paper in half. Fold the paper almost in half again as shown in Figure 15-9. Open the folded filter paper into a cone shape. Wet a funnel and place the filter paper in the funnel. Be sure not to make any holes in the filter paper. Pour the black powder into the cone.

Place five test tubes in a rack. Set the funnel in the first test tube. Pour about 10 ml of water down a stirring rod into the filter paper. Figure 15-10 will show you how to use the stirring rod to direct the water.

After all the liquid passes through the filter paper, move the funnel to the next test tube. Pour 10 more ml of water down the stirring rod. Repeat these steps until you have 10 ml of liquid in each test tube. Compare the liquids in each test tube. Was the original material a pure substance or a mixture? ★

Figure 15-10 *Pouring the water down the stirring rod.*



15-7 Paper chromatography

Materials
filter paper, marking pen, 2 clear containers, liquid cleaner, rubbing alcohol, aluminum foil, scissors, paper clips, tape, ruler

★ Cut your filter paper into two strips. Each strip should be 25 cm long and 2 cm wide. Cut one end of each strip to form a point 3 cm long. Make a small circular mark with your marking pen about 3 cm from the end of each point.

Pour liquid cleaner into one container to a depth of 1 cm. Tape a bent paper clip over the top of the container.

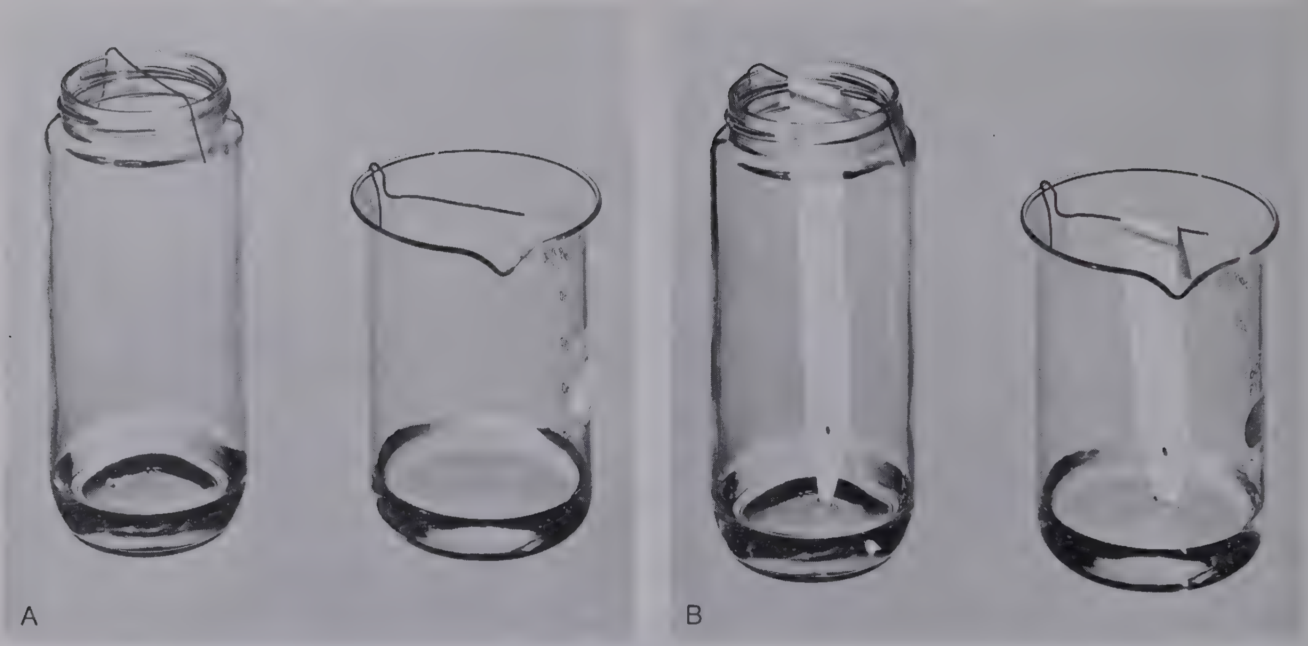


Figure 15-11 (*A*) *How to fasten the paper clip to a wide container and a narrow one.* (*B*) *Fold the filter paper over the paper clip.*

Figure 15-11A shows you how. Slip one marked piece of filter paper into the container. The point of the filter paper should just touch the bottom of the container. The paper should hang straight down the middle of the container. It should not touch the sides. Fold the top of the filter paper over the bent paper clip (Figure 15-11B). Cover the top of the container with aluminum foil.

In the second container, use rubbing alcohol instead of liquid cleaner. Follow the same steps. Look at the containers once every five minutes. After about 30 minutes, take the strips of paper out of the containers. Label the strips so that you will know how they were treated.

The series of steps you followed is called **paper chromatography** (kro-muh-TOG-ruh-fee). The colors you see on the pieces of filter paper are called **chromatographs** (kro-MAT-uh-grafs). The ink in a marking pen is a mixture of different colored dyes. The dyes are soluble in the liquids. As the liquids travel up the filter paper, they try to carry the dyes along with them.

The more soluble a dye is, the easier it is for the liquid to carry it. The more the dye is attracted to the filter paper, the more difficult it is for the liquid to move it. Some of the dyes are more soluble than others. Some of the dyes do not stick to the filter paper as strongly. So, some dyes are carried farther up the paper than others.

Chromatography is another method for separating mixtures. The substances being separated don't have to be dyes. They don't even have to be colored. Colorless substances will show up on the chromatograph if they are stained with a dye.

Each substance in a mixture keeps the set of properties that belong to it.

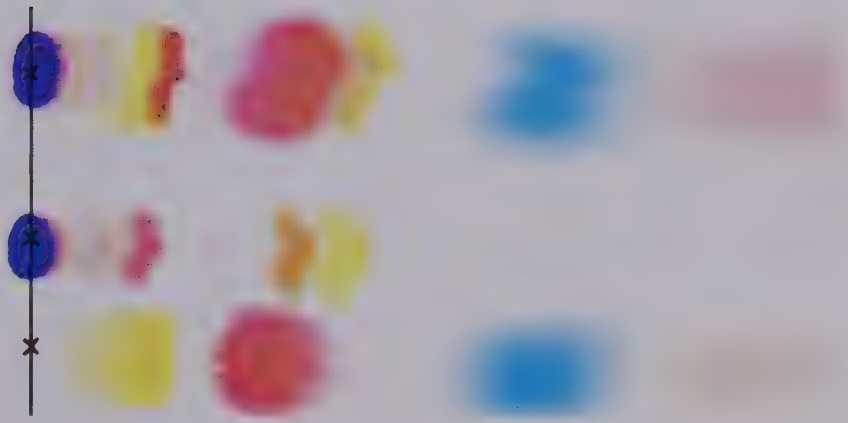
If substances differ greatly in one property, that property may be used to separate them.

Paper chromatography is one method of separating mixtures.

1. If your first attempt to separate a material by paper chromatography fails, what should you do? Why?

2. Look at the three chromatographs in Figure 15-12. One was made with brown ink, one with black ink, and one with a mixture of brown and black inks. Can you tell which is which?

Figure 15-12 *Chromatographs for What Have You Learned?*



3. If all your attempts to separate a material using paper chromatography fail, can you be sure that the material is a compound or an element?

4. If two substances have the same solubility in water at 25°C, how can you still use solubility to separate them?

SKULLDUGGERY

1. It seemed like an open and shut case. On Monday morning, the bank guard found Mr. Ashmore's body in the vault. On the floor near the body were a gun, the key to the vault, a marking pen, and a suicide note. The note read as follows: "I have been taking money from the bank for over a year. I can't pay it back and I know I will be found out soon. I am going to end it all. Farewell, cruel world!"

The suicide note was written on paper from Mr. Ashmore's desk. The gun was registered in his name and no one else's fingerprints were on the gun. The pen and the key also belonged to Mr. Ashmore. There was no reason to suspect foul play. But Detective Figueroa did not believe that Mr. Ashmore had killed himself. He suspected that someone else had stolen the money. He thought that the other person had framed Mr. Ashmore to cover up his own crime. Detective Figueroa asked the lab to do a special test for him. How did Detective Figueroa prove that it was a case of murder, not suicide?

2. One brand of aspirin advertises that it dissolves faster than other brands. Design a way to test this claim.

3. Suppose you are given five bottles that contain the substances listed in Figure 15-13. You do not know which substance is in which bottle. In order to put the correct labels on the bottles, you would have to do some tests in the lab.

Make a list of the tests you would do. Try to do as few tests as possible to identify all the substances. For example, suppose you find the solubilities of all the substances in benzene. Can you identify any of the substances for sure? If you could, you would stop testing that material.

Figure 15-13 *Table for Skullduggery.*

Substance	Density (g/ml)	Melting Point (°C)	Boiling Point (°C)	Solubility in water	Solubility in benzene	Solubility in alcohol
Acetone	0.79	−95	56	s	s	s
Chloroform	1.49	−63.5	61	ns	s	s
Diphenylmethane	1.00	26.5	265.5	ns	s	s
Wood alcohol	0.79	−98	65	s	s	s
Water	1.00	0	100	s	ns	s

FOR FURTHER READING

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Sootin, Harry. *Experiments with Water.* New York: Grosset and Dunlap, Inc., 1971. Covers fluid pressure, freezing, boiling, flow, surface tension, and Archimedes' principle.

Stone, A. Harris, and Dale Ingmanson. *Drop by Drop: A Look at Water.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1968. Experiments on displacement, composition, light transmission, density, boiling and freezing points, conductivity, and capillary action.

WHAT'S NEXT?

So far, you have been identifying substances or separating mixtures. In the next chapter, you will learn how to change one substance into another.

Unit Six

Particles of Matter

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KC 120
120

Chapter 16

Chemical Reactions

You have seen this photograph before, on page 222. At that point we talked about light and photography. But chemistry has an important part to play in photography too.

The black and white film in your camera is a sheet of plastic with a thin coating of gelatin. This coating contains silver compounds. When light hits the silver compounds, they change. The more light that reaches them, the more they change. But you cannot see the changes until the film is developed in developing fluid. The fluid reacts with the changed silver compounds and turns them into silver metal.

Different amounts of light have reached different parts of the film. Where a lot of light reached the film, the silver compounds have changed the most. These parts of the film are darkest. But where no light reached the film, the compounds have not changed at all. They will still react with light unless they are removed. So the film is treated with another chemical known as hypo. Hypo dissolves the unchanged compounds and they can be washed away with water.

The film is now a negative. To get a print, you must still go through another set of chemical steps. You don't have to be a chemist to be a photographer, but if you know something about chemistry, it certainly helps.

Recognizing Reactions

16-1 Looking for clues

You already know many properties of the compound water. At room temperature, water is a liquid. Pure water boils at 100°C and freezes at 0°C. It has a density of 1 g/ml. Many common substances dissolve in water.

You were able to use electric energy to break water down into the elements hydrogen and oxygen. The element oxygen could not be mistaken for water. It is a gas at room temperature. You can't see it. You can tell when it is around because it helps other substances to burn. Hydrogen is also a gas you can't see or smell. It can burn.

The change that occurs during the breakdown of water is called a chemical reaction. In a **chemical reaction** new substances with different properties are formed. The new substances that form are called the products. When water was changing into hydrogen and oxygen, you saw bubbles of gas in the test tubes. These bubbles were a clue that a reaction was taking place.

Materials
limewater, test tubes, straw, Alka-Seltzer, water, rubber stopper, glass tubing, rubber tubing, graduate

★ When you breathe, what gases are you breathing in? What gases are you breathing out? Try this test. Fill a test tube half way with limewater. Limewater is a solution of calcium hydroxide and water. Breathe through a straw into the test tube. What happens?

Limewater is used to test for carbon dioxide. Carbon dioxide reacts with limewater to form calcium carbonate, a compound of calcium, carbon, and oxygen. Do you think the air you breathe out is 100 percent carbon dioxide?

Put 10 ml of water in a clean test tube. Prepare the setup shown in Figure 16-1. Put 10 ml of limewater in the second test tube. Add $\frac{1}{4}$ tablet of Alka-Seltzer to the water. Stopper the test tube. Do you see any change taking place? What happens to the limewater? What is one product of the reaction you have just watched? ★

16-2 A change of temperature

There are several clues that tell you that a reaction has taken place. You have already discovered one: a gas formed. Another clue is a change in temperature.

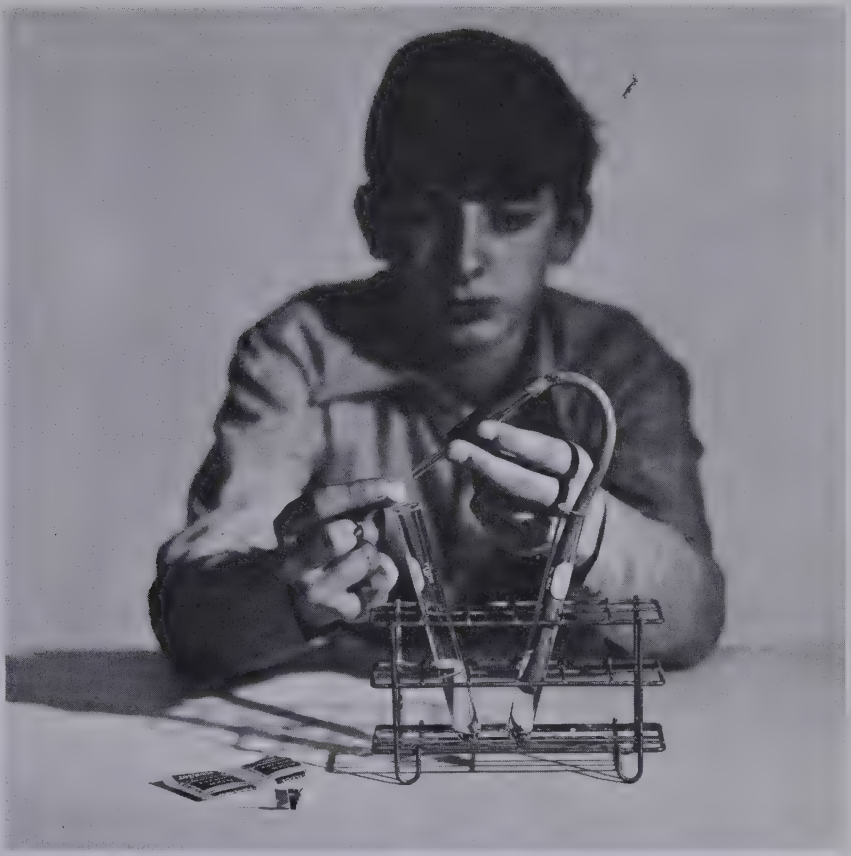


Figure 16-1 *Testing for carbon dioxide.*

Materials
zinc, dilute hydrochloric acid, test tube, beaker, cold water, graduate, thermometer, stirring rod, evaporating dish, burner, ringstand, ring, wire gauze

★ Hydrochloric acid is a solution of hydrogen chloride and water. When a small amount of material is dissolved in the water, the solution is **dilute.** When a large amount of material is dissolved in water the solution is **concentrated.** Add 10 ml of dilute hydrochloric acid to a large test tube. **Caution: Be careful not to spill any acid on yourself.** If you do get some acid on your hands, wash them right away with a lot of water. Place the test tube in a beaker of cold water. Write down the temperature of the water.

Carefully add one small piece of zinc to your test tube. Stir the water in the beaker with a glass rod. Keep the thermometer in the beaker but do not use it to stir the water. Take a temperature reading once each minute. When the zinc is all used up, add another small piece. Keep taking temperature readings. Keep adding zinc until the reaction stops. Take temperature readings for five more minutes.

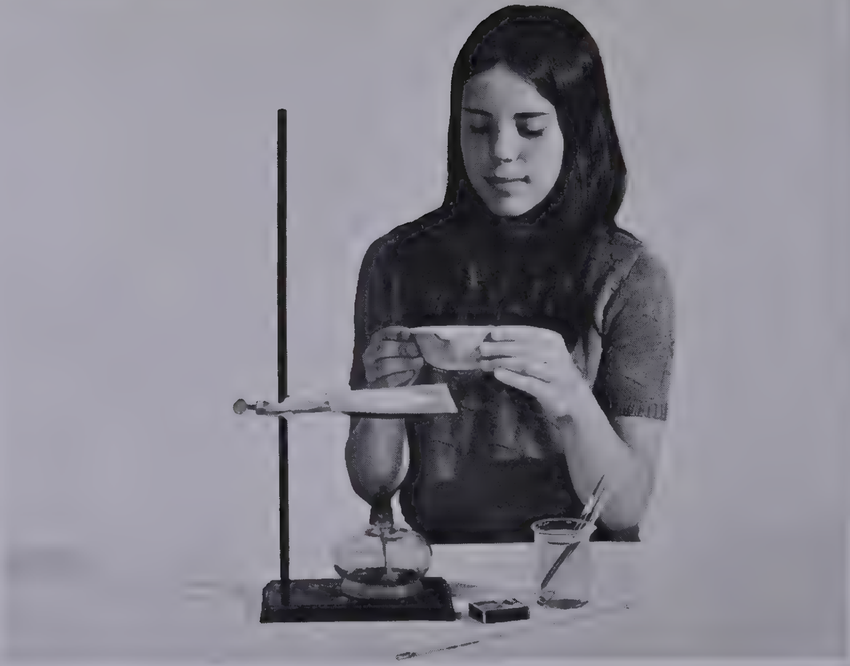


Figure 16-2 *Place the evaporating dish on the wire gauze as shown.*

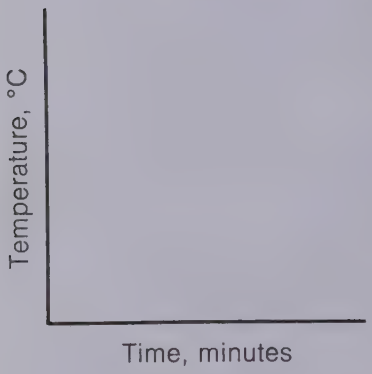


Figure 16-3 *Copy this graph to plot the reaction of zinc and hydrochloric acid.*

Pour a few milliliters of the solution in the test tube into an evaporating dish. Use the setup shown in Figure 16-2. Heat the liquid until it all evaporates. What does the solid in the evaporating dish look like? It is a compound of zinc and chlorine called zinc chloride.

Remember that zinc reacted with hydrochloric acid to form zinc chloride. You also saw a gas released. What gas do you think it was and how could you test for it? Make a graph with temperature on the Y axis and time on the X axis (Figure 16-3). Can you tell from your graph when the reaction was over? ★

16-3 Color is a clue

A reaction can produce a gas. A reaction can produce heat energy. A chemical reaction can also cause a change in color. You saw this happen in the test for iodine. The next activity is another example of a chemical reaction that causes a change in color.

Materials
ink, water, bleach, test tubes, dropper, potassium dichromate, dilute sodium hydroxide

★ Use a few drops of ink to make a solution of ink and water. What color is the solution? Add a few drops of bleach to your solution. What happens?

Now put a few milliliters of potassium dichromate solution into a clean test tube. What color is the solution? Add a dropperful of dilute sodium hydroxide. Now what color is the solution. **Caution: If you spill sodium hydroxide on your hands, wash them right away.** ★

16-4 Precipitates

Many reactions take place between substances that are in a solution. The two reactions that produced color changes took place in water solutions. So did the reaction between zinc and hydrochloric acid.

Materials
test tube, tea, iron chloride solution

★ Put a few milliliters of tea in a test tube. Tea contains tannic acid. Add a few milliliters of iron chloride solution. What happens? ★

When iron chloride and tannic acid react, they form a black compound called iron tannate. This compound doesn't dissolve very well in water. When it forms, it falls out of the solution. Substances that act in this way are called precipitates (pree-SIP-ih-tayts). Where have you heard the word *precipitation* used before?

Materials
small containers, dropper, solutions of barium chloride, copper sulfate, lead acetate, potassium chromate, and sodium sulfide

★ Make a copy of Figure 16-4 on a large piece of paper. Place one small container on each blank space. Add two or three drops of solution A to each container. Then add two or three drops of the matching solution B. Do not let the dropper touch the container. If the dropper does touch the solution, wash it off before you put it back in the bottle. If a precipitate forms in the container, write down its color in the blank space. If no precipitate forms, write NONE. In which containers did a reaction take place? ★

Figure 16-4

solution A	solution B	precipitate
barium chloride	copper sulfate	?
barium chloride	lead acetate	?
barium chloride	potassium chromate	?
copper sulfate	sodium sulfide	?
lead acetate	sodium sulfide	?
potassium chromate	sodium sulfide	?
lead acetate	potassium chromate	?

Materials
potassium ferrocyanide, copper sulfate, cotton swab, paint brush, paper

★ Use a cotton swab and some potassium ferrocyanide solution to write a message on your paper. After the writing dries, it will be invisible. Brush copper sulfate solution smoothly across the paper. What happens? The reaction of potassium ferrocyanide and copper sulfate formed a precipitate that you could see. You have just made invisible ink. ★

Did You Get the Point?

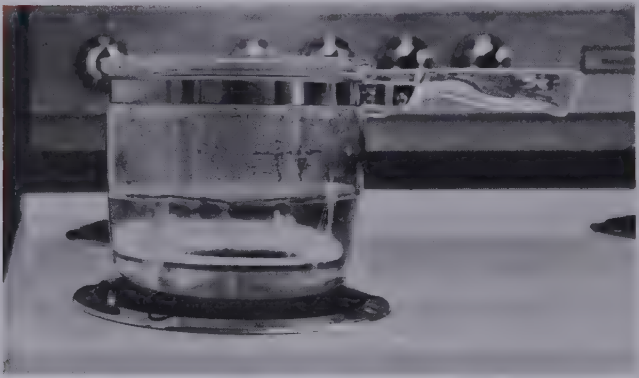
When chemicals react, new substances with different properties are formed.

A chemical reaction can be recognized by different clues: a gas forms, temperature changes, color changes, or a precipitate forms.

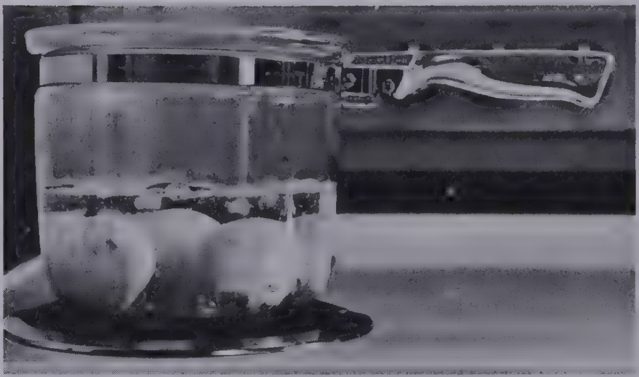
In some reactions a product forms that does not dissolve. This product is called a precipitate.

What Have You Learned?

Which of these activities involve chemical reactions?



1. Boiling water



2. Boiling eggs

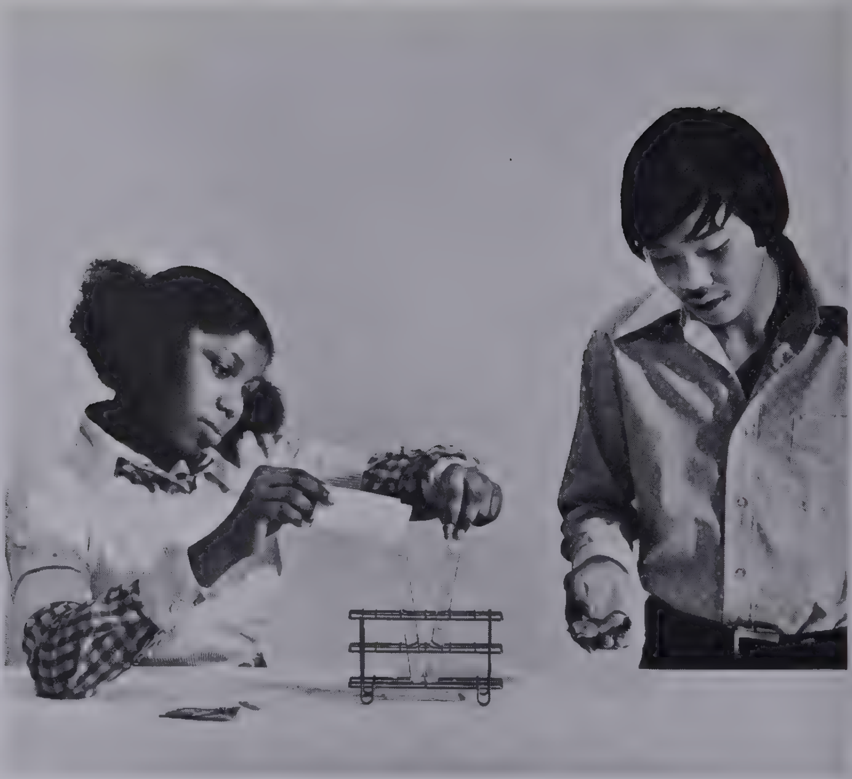
3. Scrubbing the sink with cleaning powder

4. Making an oil and vinegar dressing

5. Burning wood in the fireplace

6. Melting ice cubes

Figure 16-5 *Testing the reaction times of two forms of Alka-Seltzer.*



Speed of Reaction

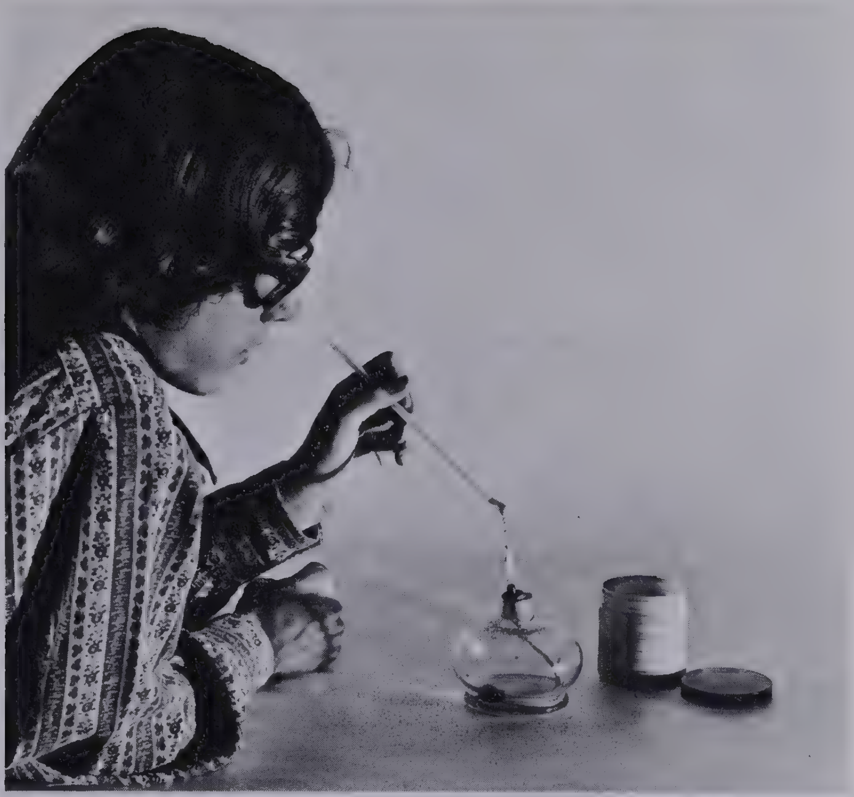
16-5 Surface Area

Materials
Alka-Seltzer, water, test tubes, spoon, stopwatch or clock

★ Split an Alka-Seltzer tablet into two equal pieces. Grind one of the pieces into powder with the back of a spoon. Put the powder on a folded piece of paper. Put the same amount of water into two test tubes. Have one person ready with the stopwatch. At exactly the same moment, add the tablet to one test tube and the powder to the other (Figure 16-5). Note how long each reaction takes. The reaction is finished when no new bubbles form. Do they both take the same amount of time? ★

The reaction between the tablet of Alka-Seltzer and water takes place at the surface of the tablet. The material in the middle of the tablet can't react until the material at the surface has reacted. When you grind up the tablet, each of the grains is like a small tablet. There is more surface,

Figure 16-6 *Be sure to wear safety glasses when doing this combustion experiment.*



so more of the Alka-Seltzer can react at the same time. This means that the reaction can go faster.

When oxygen reacts quickly with a substance, the reaction is called **combustion.** (In ordinary language, we would call it *burning.*) Combustion reactions produce a lot of heat. Often the substance that is reacting with oxygen bursts into flame. Sometimes, if the reaction is very fast, it explodes. In the next activity, you will find out how the amount of surface area affects combustion.

Materials
iron nail, steel wool, iron filings, burner, clamp, straw

★ Hold an iron nail in your burner flame. Does it begin to burn? Now try the steel wool. What happens? Put one end of your straw into some iron filings. Put your finger over the top of the straw. This should keep some filings in the other end. Slowly release your finger on the straw to sprinkle the filings over the flame (Figure 16-6). **Caution: Make sure no one is leaning over the flame.** What happens to the iron filings? Why do you think the steel wool, the nail, and the iron filings all react differently when you put them in a flame? ★

16-6 Temperature

Materials

Solution A, Solution B, test tubes, thermometer, stopwatch

★ Put 5 ml of Solution A in one test tube and 5 ml of Solution B in another. Write down the temperatures of both solutions. Have your stopwatch ready. Now pour Solution B into Solution A and start timing the reaction immediately. How many seconds pass before you can tell that the reaction is happening? How can you tell?

Wash your test tubes. Get 5 ml of Solution A in one test tube and 5 ml of Solution B in the other. Write down the temperatures of both solutions. Are they warmer or colder than the solutions you used before? Again, have your stopwatch ready and pour Solution B into Solution A. How long does the reaction take to happen? Is it faster or slower than the first time? ★

This reaction is called the "iodine clock" reaction. It is quite complicated and involves a number of steps. One of the steps is slow, and acts as a bottleneck. It slows down the whole reaction.

Imagine three people doing dishes. One clears the table, one washes, and one dries. Which step is probably the slowest? Would the whole job be finished faster if a fourth person helped to dry? Would it be faster if a fourth person helped to wash?

The steps in the "iodine clock" reaction are like the steps in washing dishes. Solution A contains potassium iodate, which is a compound of potassium, iodine, and oxygen. Solution A also contains starch. In the reaction between Solutions A and B the element iodine is released. When iodine reacts with the starch from Solution A you get a dark blue color. The color shows that the reaction is finished. What other test for iodine do you already know?

Compare your results with those of the rest of the class. Did everyone get the same reaction time? Did everyone start with the same temperature for Solution A? Did the temperature affect the speed of the reaction? If so, how?

Particles in solution are something like bumper cars at an amusement park. Suppose you have 10 cars, fixed to go exactly 5 miles per hour, and all the drivers are blindfolded. If the drivers cannot see where they are going, they will simply keep driving until they have a collision. There might be one or two collisions per minute.

Now suppose the cars are changed so that they can go 10 miles per hour. There would be more collisions per minute than before because the cars are moving faster.

The particles in solution are also moving. They react only when they collide with each other. At a higher temperature, the particles have more energy and move faster. Because they are moving faster they collide more often and the reaction goes faster.

An oxyacetylene torch gets very hot because the acetylene fuel burns in pure oxygen instead of ordinary air.

16-7 Concentration

Materials
Solution A, Solution B, test tubes, stopwatch

★ You will do the "iodine clock" reaction a third time. This time everyone will work with solutions at room temperature. But the concentrations of Solution A will vary.

Get 5 ml of Solution B in a test tube. Your teacher will give you some of Solution A. Write down how much. If it is 5 ml, use it as is. If it is less, carefully add water until the volume is 5 ml. When you add water, you are decreasing the concentration of Solution A.

Do the reaction as you did it before. How long does it take? ★

How do the differences in concentration of Solution A change the speed of the reaction?

Think of the bumper cars again. Suppose you had 20 cars instead of 10 cars. Would you have more or fewer collisions per minute? Can you explain how more particles in the same volume of solution could increase the speed of the reaction?

Did You Get the Point?

Increasing the amount of surface area speeds up a reaction.

Raising the temperature speeds up a reaction.

Increasing the concentration of one of the substances can speed up a reaction.

What Have You Learned?

1. Is the rusting of iron an example of combustion? Explain your answer?

2. Why are people warned not to throw carpet sweepings into an incinerator?

3. If you hold a match in the air it does not burst into flame. But it does burn when you strike it against a hard surface. What makes the difference?

4. See Figure 16-8.

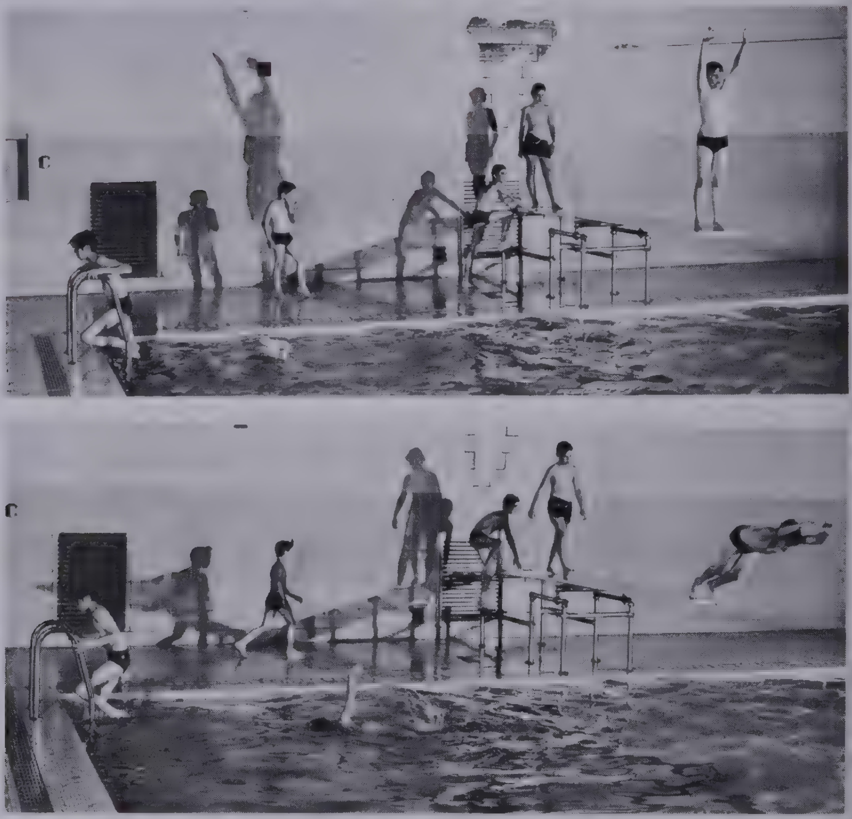


Figure 16-8 *Identify the various steps involved in this process. Do all steps take the same amount of time?*

SKULLDUGGERY

1. Clothes can be made from many different fabrics such as cotton, wool, rayon, nylon, silk, and linen. Your class should collect small pieces of many different fabrics. Your teacher will help you test these fabrics to see how they burn. Do they all burn when you bring a flame near them? Do they all continue to burn after the flame is taken away? Try to test some fabrics that have been treated so that they will not burn.

2. You know that people react to each other and that living things react to their environments. Are these examples of chemical reactions? Use the clues that you have learned for recognizing chemical reactions to help you answer this question. Do people change color when they react to each other? Do their temperatures change?

FOR FURTHER READING

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WHAT'S NEXT?

Large objects like bumper cars are easy to study because you can see them. The particles in chemical reactions cannot be seen. But you don't always have to be able to see things in order to study them. In the next chapter, you will study particles that you cannot see.

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Chapter 17

Evidence for Atoms

''Elementary, my dear Watson,'' said Sherlock Holmes. And, of course, it was elementary for the great detective. But then the author knew the answer beforehand. Even so, you can figure things out without having a great deal to go on. Detectives on any police force have to do this all the time. They are not there when a crime is committed, but they collect clues and ask the right questions until they find the answer.

You may not have thought about it, but you do it too, all the time. You walk out of the house and see that the street is wet. ''Aha,'' you think to yourself, ''It's been raining.'' Then you notice that the sun is shining brightly, there is not a cloud in the sky, and the sidewalks are dry. ''Aha,'' you say to yourself again, ''I was wrong. It must have been a street-cleaner.'' Then you remember that you heard the sound of a truck going by about fifteen minutes before.

Chemists often have to deal with things that are too small to see, even with a microscope. They have to use other kinds of clues from the ones their senses tell them about directly. In this chapter, you will learn to do some of this chemistry detective work.

Properties of Elements

17-1 Activities of metals

Materials

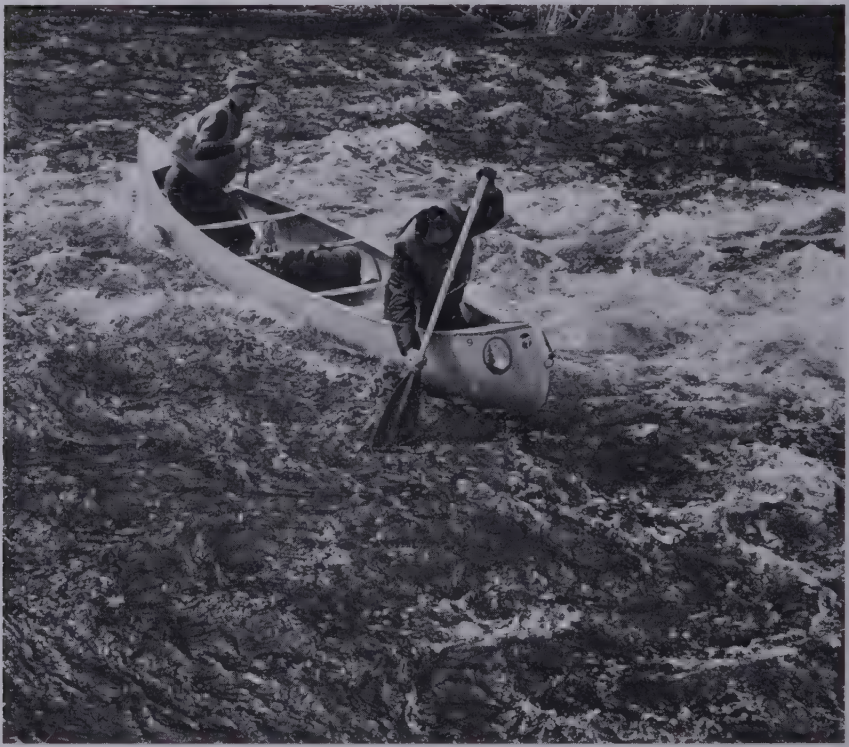
6 test tubes, rack, dilute hydrochloric acid, small pieces of iron, zinc, aluminum, magnesium, copper, and lead

In Chapter 16, you learned something about the ways substances react with each other. The more active a substance is, the more easily it reacts.

★ Put the test tubes in the rack. Pour dilute hydrochloric acid into each tube until it is about 1 cm deep. **Caution: If you spill acid, wash it off immediately.** Drop a piece of zinc into the first tube (Figure 17-1). Describe what happens in your notebook. Does a reaction occur? How can you tell? Do the same with each of the other metals, dropping a different metal into each of the six test tubes.

If the metal bubbles a lot (like Alka-Seltzer) it is very active. But if a metal does not bubble at all, it is not very active. Which of the metals you used are active? List them by how active they are, starting with the most active. ★

Some metals are much more active than the ones you used. Sodium and potassium are so active that they will burn your hand if you touch them.



Why is this canoe made of aluminum instead of iron?

Figure 17-1 *Which of these six metals do you think will have the greatest reaction in the hydrochloric acid?*

17-2 Activities of non-metals

Fluorine, chlorine, bromine, and iodine are halogens. As you learned in Section 14-7, the halogens are so active that they are dangerous.

Are oxygen, hydrogen, and nitrogen as active as the halogens? Will they burn? Are they safe to touch? Is nitrogen as active as hydrogen? What about carbon and sulfur? How active are they?

One group of non-metallic elements (non-metals) will almost never react. They are called the **noble gases.** Because they are so inactive, they are very useful in some ways. Helium (He) is a light gas like hydrogen. But, unlike hydrogen, it will not burn. So it is safer to use in blimps and weather balloons. A mixture of helium and oxygen is used instead of air for divers. Ordinary air contains nitrogen which dissolves in the blood and causes a painful condition called ''bends.'' Helium does not cause ''bends.''

Another noble gas, neon (Ne), is used in neon signs. When electricity is passed through a tube of neon at very low pressure it glows reddish orange. About one percent of the air is argon (Ar). Argon is used in electric light bulbs and fluorescent tubes.

17-3 Classification

Suppose you have a lot of records, all mixed up. If you wanted to play one particular record, you might have to look through all of them to find it. Finally you decide this is ridiculous. You have to organize the records. First you divide them into two piles: vocal and instrumental. Then you start dividing the instrumental records into smaller piles according to the lead instrument. Then you have another idea. You divide the records by type of music: jazz, rock, folk, and so on. Either way, you are dividing the records according to their properties.

Dividing things into groups according to their properties is called **classification.** When you have to classify things, there are usually several different ways to do it. Any way is right if you have a good reason for it.

Materials
objects

★ Look at the objects you are going to classify. You may divide them into any number of groups. Decide which properties you are going to use to identify your groups. Make a table like the one in Figure 17-2 (you don't have to use the properties in the table). List the objects you put in each group. When you have completed your table, compare it with other tables. How many different properties did people use to classify the objects? When two people used the same property, did they always put the same objects in their groups?

Substances can be classified in the same way as anything else. Try to classify the elements you know. Use the properties you have studied to classify your group of elements. ★

Figure 17-2 *One way to classify some materials found in a classroom.*

Solids	Liquids	Gases
eraser	water	oxygen
paper	ink	nitrogen
chalk	alcohol	carbon dioxide
clay	milk	natural gas
rock	?	?
?	?	?

Did You Get the Point?

Some metals are much more active than others.

Some non-metals are more active than others. One group, the noble gases, are very inactive.

Objects can be classified according to their properties.

Elements can be classified according to their properties.

What Have You Learned?

1. Nickel is a metal. From this information, which of these questions about the properties of nickel can you answer? (a) What is its density? (b) Is it shiny? (c) Does it conduct electricity? (d) How active is it?

2. Krypton is a noble gas. From this information, which of these questions about krypton can you answer? (a) Is it shiny? (b) How active is it? (c) Does it conduct electricity? (d) What is its boiling point?

3. Classify the objects in Figure 17-3.

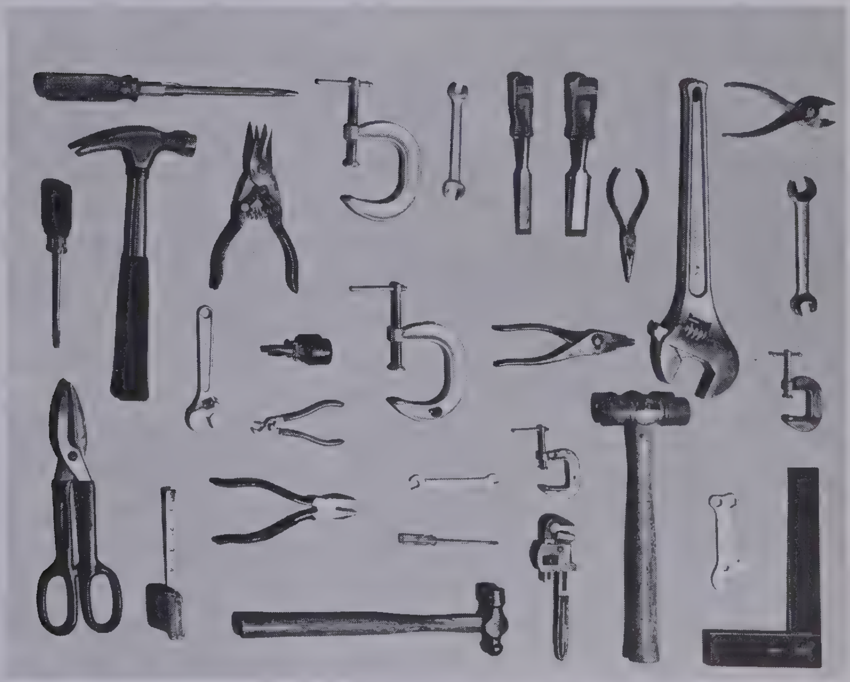


Figure 17-3 *Can you classify these objects in more than one way?*

How Can the Properties of Elements Be Explained?

17-4 What do you know about elements?

You know that some elements are metals and some are non-metals. You also know that some are more active than others. But why? What makes elements alike in some ways and different in other ways?

What do you usually do when you want to find out why something acts the way it does? For example, suppose you find an old alarm clock and want to find how it works. Probably you take it apart. That way you learn what the clock is made of and how the pieces fit together. Then you know a lot about how the clock works.

You can learn why elements act the way they do. What are elements made of? Elements are matter, so they are made of particles. To know about elements, you need to learn what particles are like and how they fit together.

But how can you find out about particles? They are very small. Maybe they are too small to investigate.

17-5 How small are particles?

To get an idea of the size of these particles, you will experiment with potassium permanganate. Potassium permanganate is useful to work with because it is easy to see.

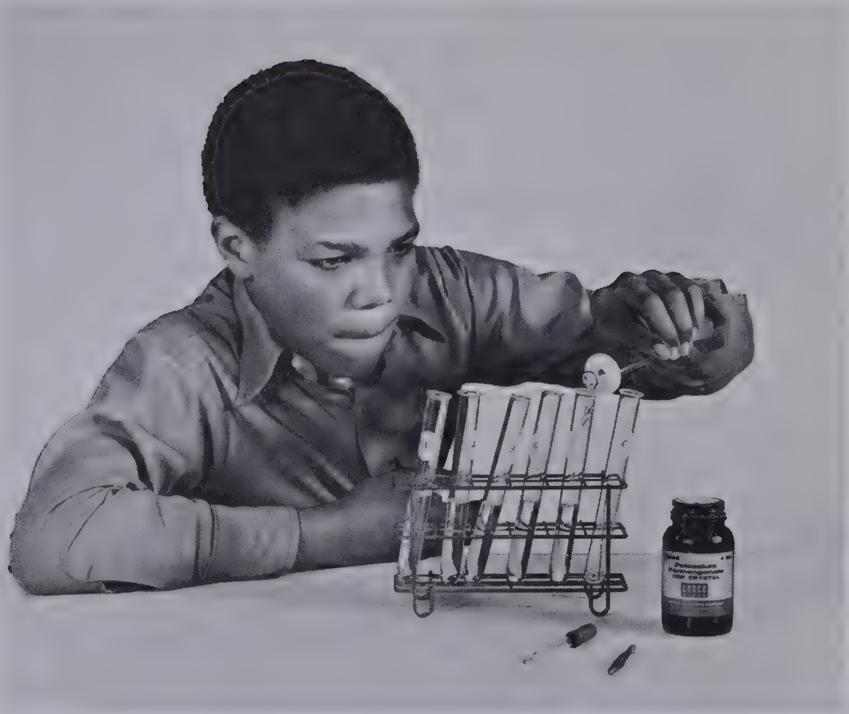
Materials
graduate, dropper, 6 test tubes, rack, masking tape, tweezers, potassium permanganate, stopper

★ Measure exactly 9 ml of water in the graduate. Using the dropper, count the number of drops needed to change the volume from 9 ml to 10 ml. Write down the number of drops.

Make labels for your test tubes with masking tape. Number the test tubes 1 through 6. Pour the 10 ml of water into tube 1. Put exactly 9 ml of water into each of the other tubes (Figure 17-4). Pick up a small piece of potassium permanganate with the tweezers. **Caution: Do not touch the potassium permanganate.** It can stain your skin. Drop the potassium permanganate into tube 1. Stopper the tube and shake it. What happens?

Use the dropper to take 1 ml of liquid from tube 1 and put it into tube 2. Stopper tube 2 and shake it. Take 1

Figure 17-4 *Be sure you counted the number of drops needed to change the volume from 9 ml to 10 ml.*



ml of liquid from tube 2 to put it into tube 3. Stopper tube 3 and shake it. Do the same thing until you have finished with tube 6.

Are the liquids in all the test tubes colored? How does tube 6 compare to tube 1? Look closely at tube 6. Can you see the potassium permanganate particles? How many potassium permanganate particles do you think are in tube 6? We will say there are 10. Then, the liquid with the potassium permanganate particles that you moved from tube 5 to tube 6 was one tenth of the liquid in tube 5. So there must have been 10 times as many potassium permanganate particles in tube 5 as there are in tube 6. That is, $10 \times 10 = 100$ particles. How many potassium permanganate particles were in tube 4? in tube 3? in tube 2? in tube 1? How many particles were there in the piece of potassium permanganate you started with? About how big is a particle of potassium permanganate? ★

Do you think there were only 10 particles of potassium permanganate in tube 6? Probably there were a lot more. So there were a lot more particles in the original piece than you figured. Do you think you could see one particle of potassium permanaganate?

17-6 How can you explain something you can't see?

Particles of matter are so small that you can't see them. Not even through a microscope. How much can you tell about something that you can't see?

Materials
boxes

★ Your teacher has put boxes around the room. Each box has a sign saying what you may do to find out what is in it. Write your observations for each box. Then write a good guess about what is in the box. ★

Even though you couldn't see what was in the boxes, you could tell a lot about what was in them by the way they behaved. Now here is a way to find out something about particles without seeing them.

Materials
pan, measuring cup, stand, burner, sugar, spoon, small jar, paper clip, string, pencil or stick

★ Bring a pan and a small jar from home. **Caution: Make sure that everything you use in this activity is clean.** Put ½ cup of water in the pan. Set the pan on a stand over a burner. While the water heats, fill a cup almost full of sugar. Stir the sugar into the water. Keep heating and stirring until the sugar dissolves.

Tie a paper clip to a piece of string. Tie the string to a pencil. Set the pencil on top of the jar so the paper clip hangs inside the jar as in Figure 17-5. Pour the sugar solution into the jar. Put the jar in a place where it will not be disturbed. Leave it for a day or two. What happens? What you have made is called rock candy. If you used clean equipment, the candy is safe to eat. ★

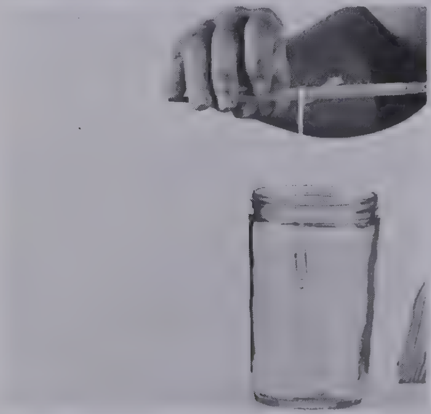


Figure 17-5

The pieces of rock candy have regular shapes. They are called **crystals.** Knowing that crystals have regular shapes, what can you say about particles of matter and how they fit together?

Materials
crystals, lens

★ Look at crystals of several substances. Use a lens to see them better. Do crystals of different substances have the same shape? What does your answer tell you about them? ★

To find out more about particles of matter, you would need very complicated equipment, so you can't do it in school. But scientists have found out a lot about particles. (See the photos on page 343.) They have a theory to explain why matter behaves as it does. You will learn about this theory in the next section.

Did You Get the Point?

To understand why elements have different properties, you must learn about the particles the elements are made of.

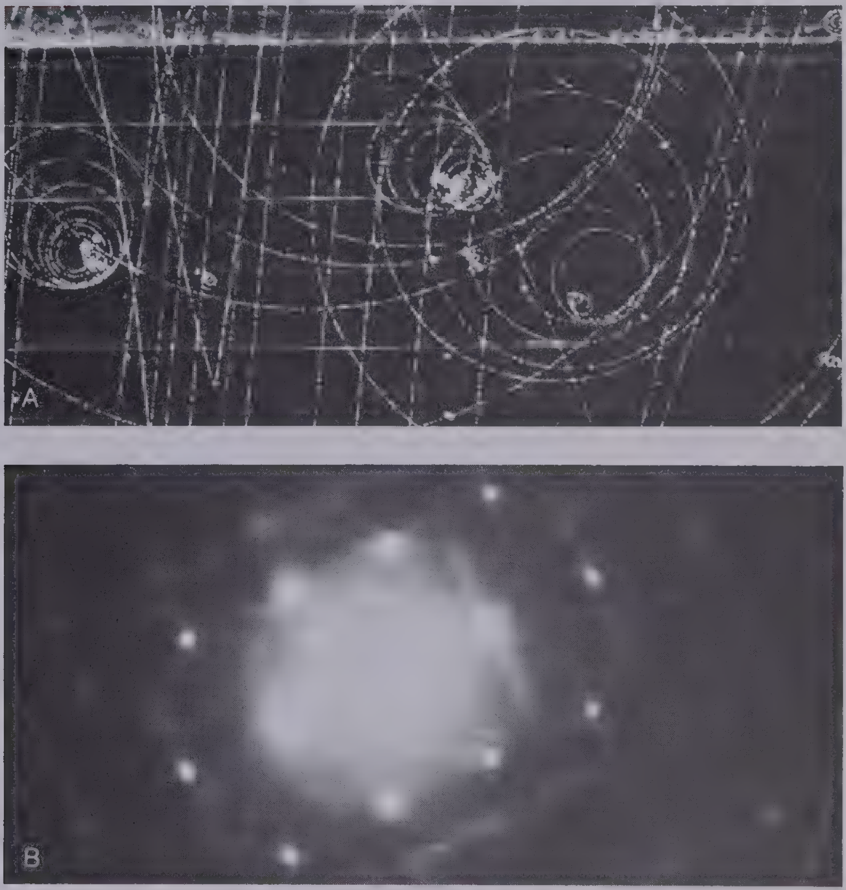
These particles are too small to see.

You can find out a lot about things by the way they behave.

Scientists can find out how particles behave, and make a theory to explain it.

What Have You Learned?

1. Suppose you have a visitor who has never seen a television set. When you show him one, he asks many questions. "Are there really people inside? Can they see us? When you turn the set off, does the program stop?" Suggest some ways to find the answer to each of these questions. **Caution: Do not test your answers on a real television set.**



Patterns from which scientists learn about particles. (A) Tracks of charged particles moving in a magnetic field. (B) A pattern showing the crystal structure of the element silicon.

The Atomic Theory

17-7 Atoms

One particle of an element does not have all the properties of a larger piece of the element. The particle does not have a color or a melting point, and it would be hard to tell how well it conducts electricity. But a particle of an element does have some properties that belong only to that element. From these properties, scientists can tell that it is a particle of that element. The smallest particle that can be identified as a particle of an element is called an **atom.**

An atom is made of smaller particles: electrons, protons, and neutrons. As you learned in Chapter 6, an electron has a negative charge and a proton has a positive charge. A **neutron** has no charge. A neutron and a proton have about the same mass (Figure 17-6). The mass of an electron is only about $\frac{1}{2000}$ of the mass of a proton or neutron.

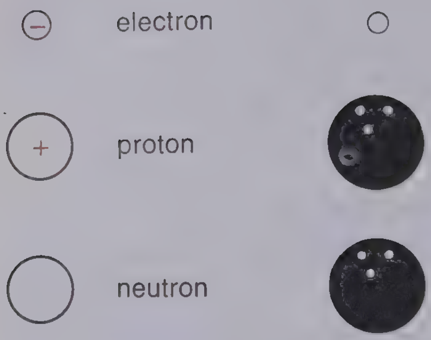


Figure 17-6 *A proton or neutron has almost 2000 times as much mass as an electron. This is about like a bowling ball and a pingpong ball.*

The protons and neutrons are held together in the center of the atom. This part of the atom is called the **nucleus.** The electrons move around the nucleus. They move so fast that it is not possible to tell where each electron is at any moment. The electrons form a kind of cloud around the nucleus. Figure 17-7 gives you a simple idea of an atom with its nucleus and its cloud of electrons. Scientists call this kind of simple picture a **model.** Of course no one knows what an atom really looks like. But a picture helps people think about atoms.

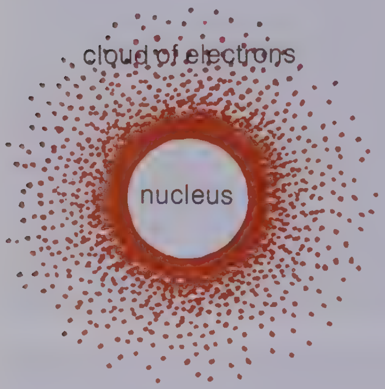


Figure 17-7 *A model of an atom with its nucleus and cloud of electrons. The thickest part of the cloud shows where the electrons are most of the time.*

Because the electrons are negative, they repel each other. The nucleus is positive because its protons are positive. Why aren't the electrons pulled in to the nucleus instead of moving around it? No one knows why. And what about the nucleus? The protons ought to repel each other. So the nucleus ought to fly apart. There must be some special force that holds it together. Some scientists think the force has something to do with the neutrons. But no one knows for sure.

Everything you are learning about atoms is part of a theory. The theory has not been proved. Sometimes, when a new fact is learned, a theory has to be changed a little. But most of the time the atomic theory fits the facts very well. So almost everyone thinks that it is true.

When you worked with charged objects in Chapter 6, you learned that most objects are not charged. Since matter is made of atoms, atoms must have no charge. This means that atoms must have the same number of electrons as protons.

All the atoms of a particular element have the same number of protons. The protons are all in the nucleus. The number of protons in an atom of an element is called the **atomic number** of that element. Atoms of different elements have different numbers of protons. So no two elements have the same atomic number.

Because the mass of a proton or neutron is about 2000 times the mass of an electron, almost all the mass of an atom is in the nucleus. The mass of the electrons hardly counts. An atom is very tiny. Its mass in grams is such a small number that there is no sense in using it. So scientists use a special unit for the mass of an atom. This unit is the mass of one proton or neutron. A proton or a neutron has a mass of one unit. The **atomic mass** of an atom is the total number of protons and neutrons. For example, an atom of helium has two protons and two neutrons. So its atomic mass is four.

Figure 17-8 shows the number of electrons, protons, and neutrons in atoms of some common elements.

Figure 17-8 *Table of elements.*

element	symbol	number of electrons	atomic number (number of protons)	average number of neutrons	atomic mass (number of protons and average number of neutrons)
Hydrogen	H	1	1	0	1
Helium	He	2	2	2	4
Carbon	C	6	6	6	12
Oxygen	O	8	8	8	16
Sodium	Na	11	11	12	23
Chlorine	Cl	17	17	18	35
Iron	Fe	26	26	30	56
Iodine	I	53	53	74	127
Mercury	Hg	80	80	120	200

Why does Figure 17-8 say "average number of neutrons"? Not all atoms of an element have the same number of neutrons. So not all atoms of an element have the same atomic mass. The number of neutrons in an atom does not affect most of its properties. The atomic mass of an element is the average atomic mass of its atoms. For example, half the atoms of bromine have an atomic mass of 79. The other half have an atomic mass of 81. So the atomic mass of bromine is 80.

17-8 The masses of elements

Using complicated equipment, scientists can find the mass of an atom. What does this mean in the real world? A tiny piece of an element contains billions of billions of atoms. How can you find its atomic mass? Scientists can find out when two samples of matter have the same number of atoms. Will that help?

Materials
coat-hanger balance, standard masses, 2 sets of objects

★ Set up your coat-hanger balance. You will use two kinds of objects, called A and B. Put a set of A objects in the left cup. Do not count them. Using your standard masses in the right cup, find the mass of the A objects.

Take out set A and put a set of B objects in the left cup. Do not count them. There are the same number of B objects as of A objects. Find the mass of the B objects.

Compare the mass of the A objects with the mass of the B objects. How would the mass of one of the A objects compare with the mass of one of the B objects? ★

You did not know how many of each kind of object there were, but you knew that there were the same number of each. You knew the total masses. With these two facts, you could compare the masses of one of each kind of object.

Scientists do the same thing. When they have equal numbers of atoms of two elements, they can compare the masses of one atom of each element. Once they found the actual atomic mass of one element, they could find the atomic masses of all the elements.

LIBRARIAN

Charts and tables help to organize information. But how would you organize all the information in all the science books? Organizing is an important part of a librarian's work. You would never be able to find any book you needed if all the books in a library were put on the shelves any old way.

The job of numbering and organizing books is done by a library cataloger. All the books on the same subject are grouped together on the shelves. The cataloger also prepares files that tell you where a book is on the shelves.

There are many different kinds of libraries. You probably use public libraries and school libraries. Colleges, museums, and many businesses also have libraries. The librarian of an electronics company needs a different background and interests from the librarian of an art museum. Most librarians are college graduates. If you are interested in library work, a part-time job may help you decide.

17-9 Chemists can "count" atoms

We have been talking about the mass of individual atoms, but chemists deal with large numbers of atoms rather than with individual atoms. How can chemists keep track of so many atoms, which are too small to be seen?

In Section 17-8, you knew how the numbers of objects compared, so you were able to find out how the masses of individual objects compared. Maybe this method works the other way too.

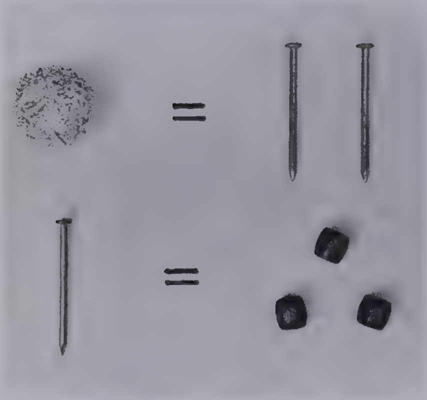


Figure 17-9 *Compare the relative mass of these three kinds of objects.*

Suppose, for example, that an aluminum foil ball has the same mass as two small nails and that a nail has the same mass as three beads. If you choose one of these objects as a standard, the other objects can be compared with it. The mass of each object can be described in terms of the standard. If you and your classmates choose the mass of a small nail as your standard, you can assign it a mass of, say, 15. Then you can describe the mass of an aluminum ball as 30 because an aluminum foil ball has twice the mass of a nail. What would be the relative mass of a bead in Figure 17-9?

If you have a box of nails and beads mixed together, is counting all of them the only way to compare how many nails and beads there are? You could separate the nails and beads by picking the nails up with a magnet. Then you find out that you have 15 g of nails and 10 g of beads. How do the numbers of nails and beads compare? (Remember in our system the relative mass of a bead is 5.)

Using a similar method—but a much more complicated one—chemists have worked out the relative masses of atoms of all the elements.

In the next experiment you are going to keep track of the number of zinc atoms that react with a certain number of copper particles. You and your classmates will use the same volume of copper sulfate solution so each of you will have about the same number of copper particles. But you will use different masses of zinc.

Materials
graduated cylinder, 250-ml beaker, 8-oz styrofoam cup, thermometer, copper sulfate solution, zinc powder, dilute hydrochloric acid, balance

★ Find the mass of the styrofoam cup. Pour 150 ml of copper sulfate solution into the cup. Put a thermometer into the solution in the cup and leave it there while you measure out 2-g samples of zinc powder. Your teacher will tell you how many 2-g samples you are going to need.

You can stir the solution with your thermometer because it will not break if it hits the side of the styrofoam cup.

When the temperature of the solution is steady, write it in your notebook as the original temperature of the solution. Slowly add 2 g of zinc powder while you stir the solution with your thermometer. Keep stirring until the temperature is steady. In the same way continue adding samples of zinc until you have added all your samples. When the temperature stops rising, write down the steady temperature as the final temperature of the solution.

Stop stirring and remove the thermometer, making sure that no solid particles stick to it. Let the solid settle. Carefully pour most of the liquid off into a beaker. Don't let the liquid carry any of the solid particles out of the cup. Compare the color of the new solution with the color of copper sulfate solution. Has there been a chemical reaction? How do you know?

Pour 20 ml of dilute hydrochloric acid into the cup with the solid. Move the cup around slowly to mix the contents. Half fill the cup with water. Let the particles settle again and carefully pour off as much water as you can without losing any of the solid. Write your name on your cup and set it aside to dry. The next day find the mass of the cup and the dry particles. Subtract the mass of the empty cup from the mass of the cup and the solid. How much solid was formed in the reaction? What do you think the product is? ★

Compare the mass of zinc you added with the mass of the solid you found in the cup. The masses of zinc and copper atoms are about the same. What can you assume about the number of zinc atoms added and the number of copper atoms produced?

Did You Get the Point?

The smallest particle of an element that is really that element is called an atom.

An atom has a nucleus of protons and neutrons, and electrons moving around the nucleus.

The atomic number is the number of protons in an atom. Every element has a different atomic number.

The atomic mass is the total number of protons and neutrons in an atom.

The atomic masses of elements can be compared.

What Have You Learned?

1. The nucleus of a particular atom has 13 protons and 14 neutrons. What is the atomic number of the element? What is the atomic mass?

2. Think of several ways to convince a friend that matter is made of atoms.

SKULLDUGGERY

1. Arrange some objects in a box. See how much your classmates can tell about the objects without looking inside.

2. One company says its salt clings to food better because of its shape. Find out if salt crystals can have different shapes.

FOR FURTHER READING

Asimov, Isaac. *The Noble Gases.* New York: Basic Books, Inc., Publishers, 1966. The discovery and identification of the noble gases and their newly-found chemistry.

Seaborg, Glenn T., and Evans G. Valens. *Elements of the Universe.* New York: E. P. Dutton, 1958. Elements, atoms, and radioactivity.

Wohlrabe, Raymond A. *Crystals.* Philadelphia: J. B. Lippincott Co., 1962. History, structure, and properties of crystals as well as directions for growing.

WHAT'S NEXT?

The chemists' method of "counting" atoms increased their interest in the chemical behavior of atoms. They learned that a hydrogen atom, for example, never combines with two atoms of oxygen. But an oxygen atom does combine with two atoms of hydrogen. Using H_2O for water tells us that water is made from twice as many hydrogen atoms as oxygen atoms. In the next chapter we will learn more about how atoms react and how chemists keep track of them.

Chapter 18

Molecules and Compounds

A pattern like this graceful spiral seashell is pleasant to look at. But there is more to it than that. The pattern can tell us something about the animal that lives inside.

Patterns are useful clues for scientists. Some patterns are right there, waiting to be found. Sometimes facts or ideas have to be picked out and fitted into a pattern before they make sense.

There are more than a hundred elements. Each one has its own properties. You might not think that so many different elements could fit into a pattern, but they can. And from the pattern you can tell the properties of an element that you are not familiar with.

Chemists Deal With Large Numbers of Atoms

18-1 Evidence for an atomic model

Electricity breaks down water into hydrogen and oxygen. When you did this experiment in Section 14-1, about twice as much hydrogen as oxygen was formed. You could do the experiment again and again, changing the amount of water and the time the current is left on. But you would always get twice the volume of hydrogen as of oxygen. Because of this, we can assume that definite amounts of hydrogen and oxygen always react together to form water. How can we explain this relationship?

Can we use an atomic theory of matter to explain the composition of water? The **composition** of a compound is the relative amount of each element in a compound. You know that the best way to measure amounts of matter is by mass. So we will discuss the masses of hydrogen and oxygen formed when water is broken down.

Regardless of how much water is broken down, chemists always find that the mass of oxygen formed is about eight times the mass of hydrogen. For example, if 18 g of water is broken down, you would get 16 g of oxygen and 2 g of hydrogen.

In Chapter 17 you compared the numbers of nails and beads by finding the total masses. We will use the same idea now to compare the numbers of hydrogen and oxygen atoms in water. Remember in Section 17-9 we talked about a small nail that had three times the mass of a bead. If you had 10 nails and 10 beads, the nails would have three times the mass of the beads. Or even if you had a hundred nails and a hundred beads, the nails would still have three times the mass of the beads.

Chemists know that an oxygen atom has 16 times the mass of a hydrogen atom. So if you had an equal number of oxygen and hydrogen atoms, the oxygen would have 16 times the mass of the hydrogen. But when water is broken down, the oxygen that is released has only eight times the mass of the hydrogen. Is there an equal number of oxygen and hydrogen atoms released? Which kind is there more of? You can figure out that water is made from twice as many atoms of hydrogen as atoms of oxygen.

In Chapter 14 you found out that iron rusts when it combines with oxygen. This reaction occurs faster if the iron is heated.

Materials
steel wool, crucible, triangle, ringstand, ring, burner, and balance

★ Find the mass of a crucible. Press a small piece of clean steel wool into your crucible. Use enough to almost fill the crucible. Find the mass of the crucible and steel wool together. Place the crucible on a triangle supported by a ringstand as in Figure 18-1. Heat the crucible gently at first. Gradually increase the flame and heat the crucible strongly for about 10 minutes. Allow the crucible to cool. Find the mass of the crucible and its contents. Heat the crucible strongly for another 10 minutes. Cool it and find the mass again. Repeat this procedure until there is no change in mass when the crucible is heated.

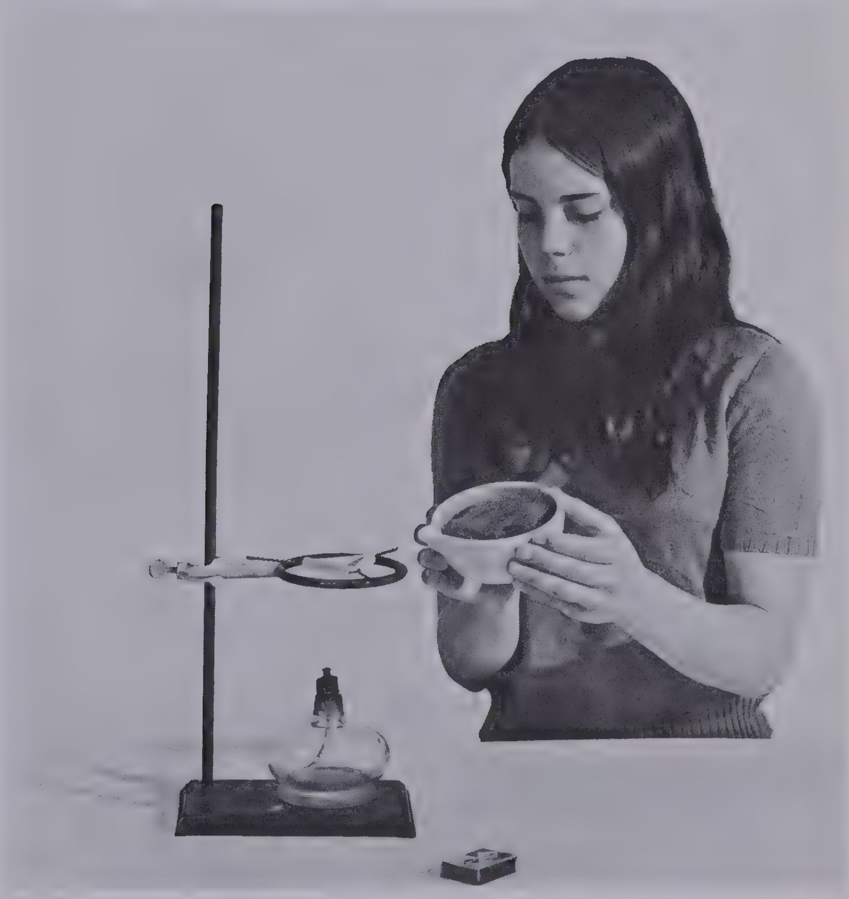


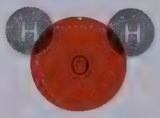
Figure 18-1

Examine the solid in the crucible. How do you know that a reaction has taken place? Why did the mass of the steel wool change? Can you explain why the mass did not change after the crucible had been heated several times?

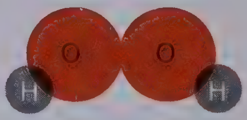
What is the mass of steel wool that you started with? How much iron oxide was formed? What is the mass of the oxygen in the compound?

Iron atoms have about $3\frac{1}{2}$ times as much mass as oxygen atoms. Working with your teacher and classmates, see if you can compare the numbers of iron and oxygen atoms in the compound. ★

A compound is made from atoms of certain elements. Not only that, the relative number of each kind of atom is always the same. When the relative number of each kind of atom is different, it is a different compound. For example, water is made from the combination of two hydrogen atoms and one oxygen atom. But when two hydrogen atoms combine with two oxygen atoms, a completely different compound is formed—hydrogen peroxide. Hydrogen peroxide is an active compound that is often used to wash cuts and scratches because it slows down the growth of germs. You know that hydrogen peroxide breaks down easily and is a good source of oxygen.

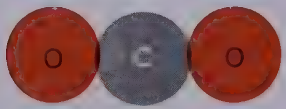


water

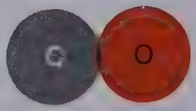


hydrogen peroxide

Carbon and oxygen usually combine to form carbon dioxide, which is an inactive and harmless gas. But carbon and oxygen can form a different compound, particularly if the oxygen is in short supply. This compound is carbon monoxide. It is a very active, poisonous gas. Even though they have the same kinds of atoms, these two compounds are different because the number of oxygen atoms in each



carbon dioxide



carbon monoxide

is different. Carbon dioxide has two oxygen atoms for each carbon atom, and carbon monoxide has only one oxygen atom for each carbon atom. For the same mass of carbon, carbon dioxide has twice as much oxygen as carbon monoxide has.

18-2 Atomic structure affects the way atoms react

Chemistry deals with large amounts of matter rather than with single atoms. But knowing the structure of atoms can help you understand why some elements are more active than others.

You have learned that atoms of different elements have different numbers of protons and electrons. The number

Smog is a mixture of many materials, including carbon dioxide and carbon monoxide. You cannot see or smell carbon monoxide, but it is very poisonous.

of protons in the nucleus of an atom, its atomic number, determines the kind of atom it is. For example, only oxygen atoms have 8 protons. Also, you remember that an atom is electrically balanced. That is, it has the same number of electrons and protons.

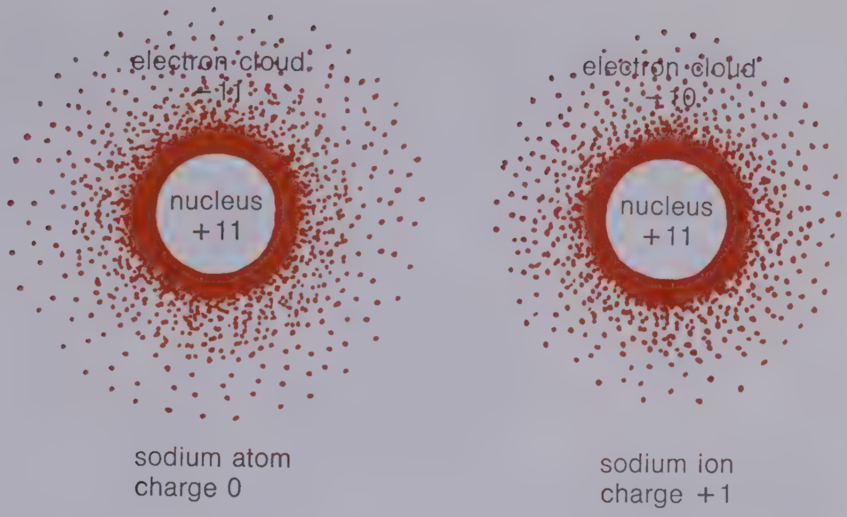
Since an oxygen atom has 8 protons in the nucleus, it also has 8 electrons moving around the nucleus. Neon, on the other hand, has an atomic number of 10, which tells us that a neon atom has 10 protons. This means it also has 10 electrons. A helium atom has 2 protons and 2 electrons, and an argon atom has 18 protons and 18 electrons.

Helium, neon, and argon are three of the noble gases. The noble gases usually do not react with other elements. Because they are not active, they are said to be stable. A **stable** element does not usually react with other substances. Because the noble gases are stable, they help us to understand the chemical activity of other elements. Why is sodium, with one more electron than neon, an active metal? And why is chlorine, with one less electron than argon, an active non-metal? The difference between the numbers of electrons is the important thing.

Chemists discovered that a sodium atom loses an electron when it forms a compound. A sodium atom loses one electron quite easily but holds tight to the rest of its electrons. The atomic theory explains that this one electron is farther from the nucleus than the others. Because of the greater distance between the electron and the nucleus, the outermost electron is not held as tightly as the others.

When a sodium atom loses an electron, a different particle is formed. The nucleus is not changed. It still has 11 protons. But since one electron is missing, the positive charge of one of the protons is not balanced by a negative electron charge. The sodium particle is no longer an electrically-balanced atom. It has a charge of +1. The particle is now a sodium ion. An **ion** is a particle with unequal numbers of protons and electrons. When a sodium atom loses an electron, it becomes a positive sodium ion (Figure 18-2). The ion has different properties from the atom because the sodium nucleus is surrounded by only 10 electrons instead of 11. A sodium ion is more stable than a sodium atom.

Figure 18-2

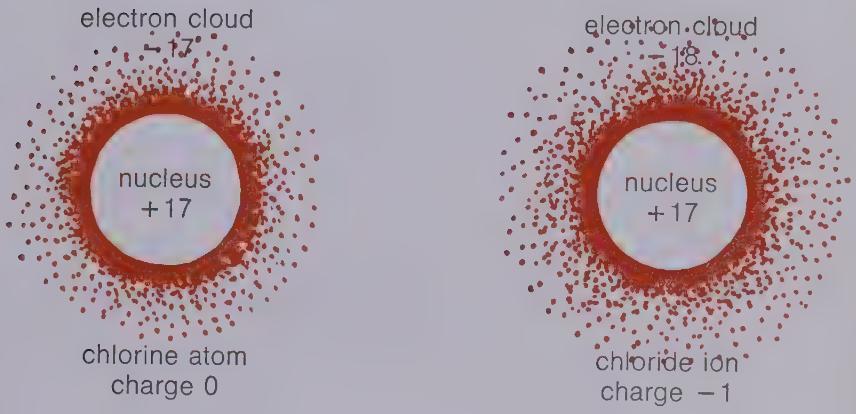


sodium atom
charge 0

sodium ion
charge +1

Unlike sodium, a chlorine atom usually gains one electron when it forms compounds. When a chlorine atom gains an electron, it has 18 electrons. The nucleus still has 17 protons, but now there is an extra electron moving around the nucleus. When a chlorine atom gains an electron, it becomes a chlorine ion that has a −1 charge (Figure 18-3). A chlorine ion is called a chloride ion.

If chlorine and sodium come in contact, there is an explosion and a white compound forms. The two active and dangerous elements change into a totally different substance that is neither poisonous nor dangerous. The new substance is sodium chloride—ordinary table salt.



chlorine atom
charge 0

chloride ion
charge −1

Figure 18-3

In the reaction of chlorine and sodium, electrons are lost and gained. A sodium atom becomes a positive ion by losing its outermost electron. The chlorine atom takes the electron and becomes a negative chloride ion. Because of their opposite charges, the ions cling together and form table salt.

Chemists looked for a pattern in what they knew about the way different elements react. They compared the atomic structure of sodium and chlorine with the way these elements react. In a similar way, chemists studied all the elements. They used their model of the atom to explain how substances behave in reactions. Chemists believe that the chemical behavior of an atom must depend on the number of its electrons and the way they are arranged. Atoms lose or gain electrons to form stable arrangements of electrons that are like the noble gases. Also, only the outermost electrons are used in forming compounds. The rest of the atom, the nucleus and the electrons closer to the nucleus, are unchanged in chemical reactions.

Did You Get the Point?

Every bit of a compound is made of the same kinds and numbers of atoms.

An atom has an equal number of protons and electrons.

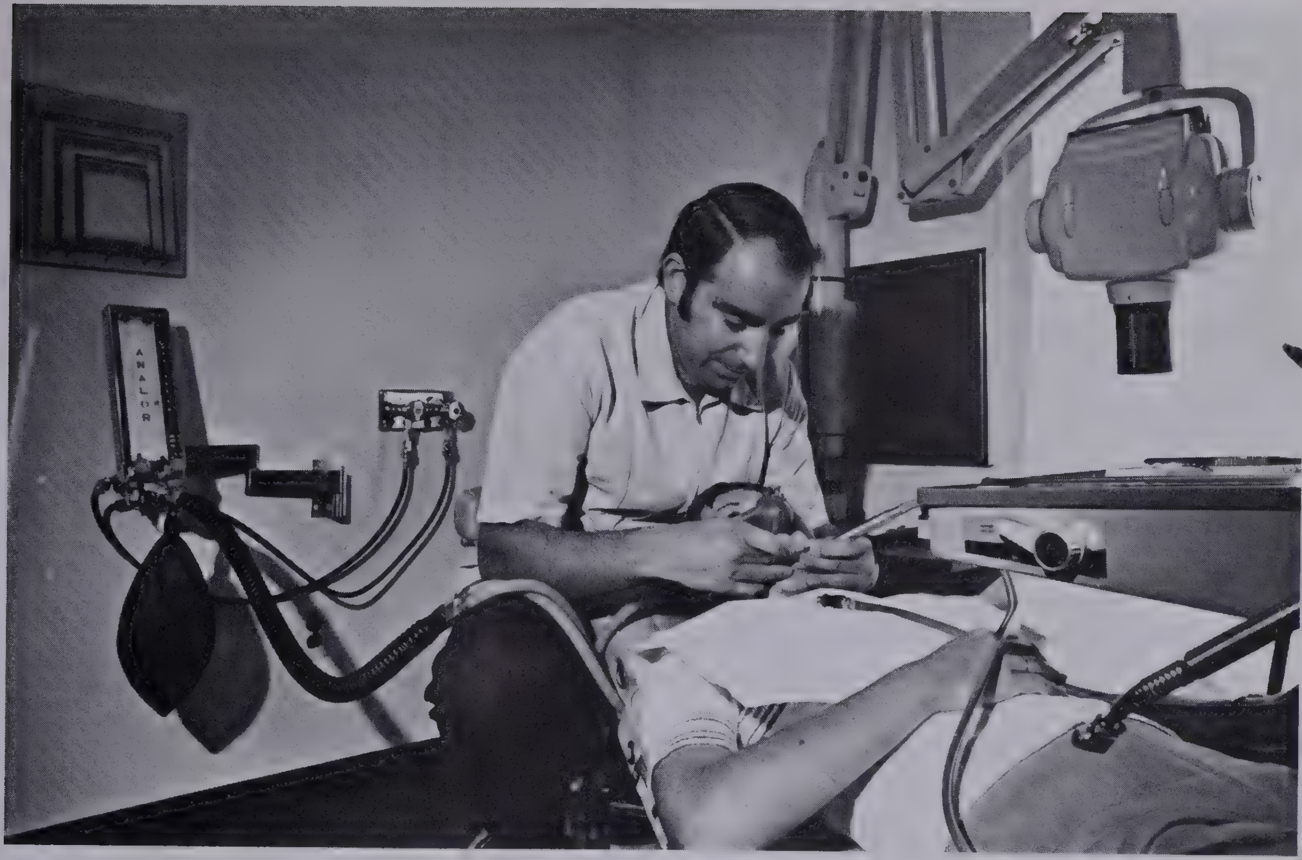
When an atom loses an electron, a positive ion is formed.

When an atom gains an electron, a negative ion is formed.

A stable element or compound does not usually react with other substances.

The chemical behavior of an element depends on the number and arrangement of electrons.

A reaction occurs when an atom loses an electron to another atom or gains an electron from another atom.



Some dentists use laughing gas, an oxide of nitrogen, to keep their patients from feeling pain. The patient breathes a mixture of laughing gas and oxygen from a nosepiece.

What Have You Learned?

1. There is a colorless, sweet-smelling oxide of nitrogen, called laughing gas. Another oxide of nitrogen is a very active, poisonous gas. Both compounds are made from nitrogen and oxygen atoms. But they are different compounds. Why?

2. A teacher put a piece of sodium into a bottle filled with chlorine and then quickly put the cover back on. The sodium burst into flames immediately, but it burned only a few seconds. There was still a small piece of sodium left in the jar. Why didn't all of the sodium react?

3. When an aluminum atom reacts, it loses three electrons. What is the charge of an aluminum ion?

Atoms Combine to Form Molecules and Compounds

18-3 Molecules and formulas

Sodium and chlorine are opposite kinds of elements. A sodium atom tends to lose an electron, and a chlorine atom tends to gain electrons. So they form ions when they react. But very often atoms react in a different way. For example, hydrogen and chlorine react without gaining or losing electrons.

A hydrogen atom holds its single electron more tightly than a sodium atom holds its outermost electron. So when a chlorine atom and a hydrogen atom react, the chlorine atom does not take hydrogen's electron. Instead hydrogen and chlorine share two electrons between them. That is, a chlorine atom shares one of its electrons with a hydrogen atom. And the hydrogen atom shares its single electron with the chlorine atom. In this way, hydrogen has some control over two electrons, and chlorine has some control over eighteen electrons (Figure 18-4).

The shared electrons move around the nuclei of both atoms. But chlorine has more control over the electrons because its nucleus has a stronger attraction for electrons than the hydrogen nucleus has. Imagine two teams playing basketball. If one team is much stronger than the other, the stronger team would control the ball most of the time. But the underdogs would get the ball some of the time, even though the final score may be 93–48.

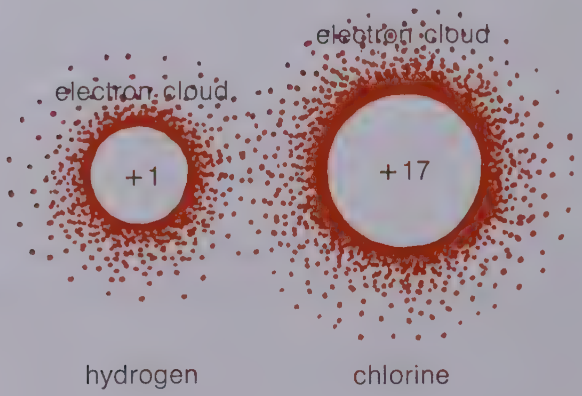


Figure 18-4 *When a hydrogen atom and a chlorine atom react, their electron clouds overlap and they share an electron.*

A hydrogen atom and a chlorine atom share electrons, so they stay together and form a molecule. A **molecule** is an uncharged particle made from two or more atoms.

You have seen that different substances can share electrons. But can atoms of the same substance share electrons? The answer is yes.

Two chlorine atoms share electrons to form a molecule of chlorine gas. Two hydrogen atoms can share their electrons, too. In fact, in many elements that are gases, two atoms share electrons to form molecules of the gas. Each pair of atoms of the same element share electrons equally.

Chemists show that a gas is composed of molecules of two atoms by writing $_2$ to the right of the symbol. H_2 is the formula for hydrogen gas. A chemical **formula** is a way of showing the composition of a substance by using symbols. It is a shorthand for chemists. H_2 shows that each molecule of hydrogen is made from two atoms of hydrogen. F_2, N_2, and O_2 are formulas for fluorine, nitrogen, and oxygen.

The formula H_2O tells us that water contains two atoms of hydrogen for each atom of oxygen. (We do not write O_1. The letter by itself shows that there is only one of that kind of atom.) HCl is the formula for hydrogen chloride. What is the formula for neon gas?

18-4 Writing formulas

Some atoms gain or lose electrons in reactions and become ions. Some atoms share electrons in reactions. But it is easier to write formulas if we treat both types of atoms in the same way—that is, as if they all became ions.

There is another property of atoms that we have to think about when we are writing formulas. It is called the combining capacity. The **combining capacity** of an element is the number of electrons that an atom of the element loses, gains, or shares in forming compounds. If an atom loses electrons, its combining capacity is positive. For example, sodium gives up one electron to form a positive ion. So the combining capacity of sodium is +1. All metals have positive combining capacities.

If an atom gains electrons, its combining capacity is negative. For example, chlorine gains one electron to form a negative ion. So the combining capacity of chlorine is -1. Non-metals have negative combining capacities.

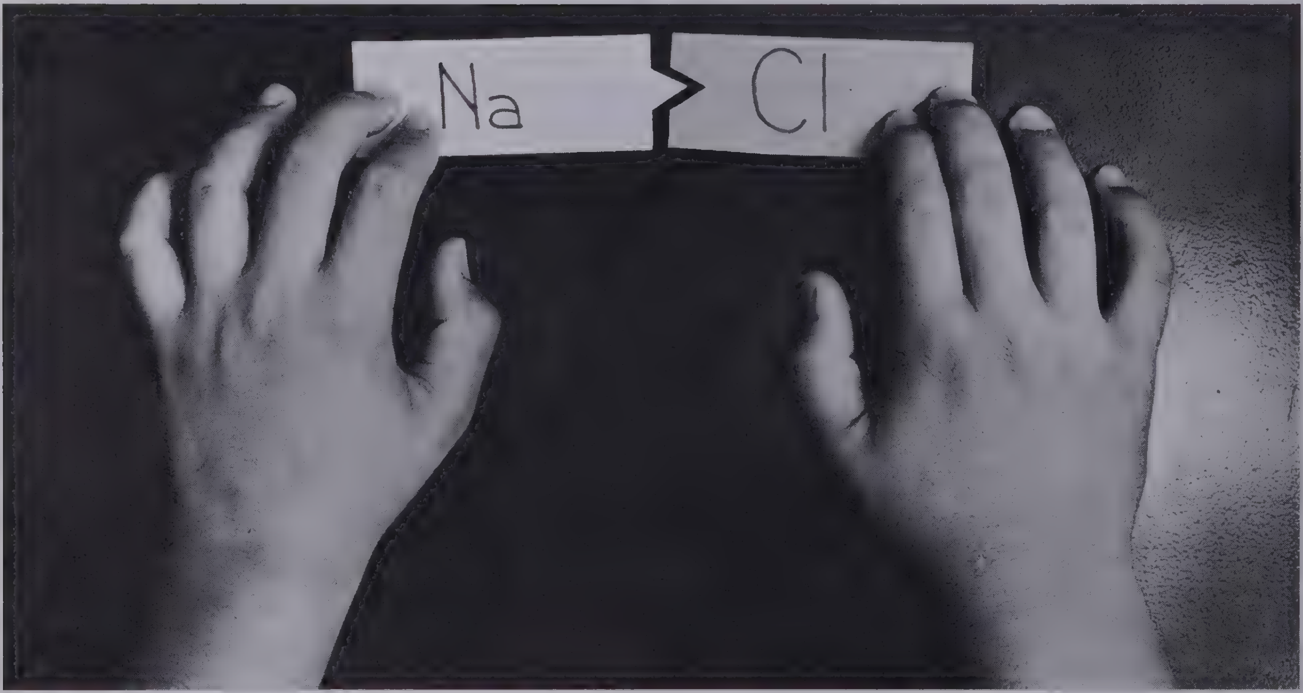
The formula for sodium chloride is NaCl. The electron lost by the sodium atom is gained by the chlorine atom. In other words, the combining capacity of sodium $(+1)$ balances the combining capacity of chlorine (-1).

Hydrogen atoms and oxygen atoms combine to form water molecules by sharing electrons. But we simply balance the combining capacities of hydrogen and oxygen when we use our system of writing formulas. The combining capacity of oxygen is -2, that is, oxygen atoms gain two electrons. Hydrogen has one electron to lose, so its combining capacity is $+1$. For every oxygen atom (-2), there have to be two hydrogen atoms $(2 \times +1)$, to make the combining capacities balance. We show this by writing the formula of water as H_2O.

Materials
cutout "atoms"

★ Put different cutout "atoms" together to form several "compounds." Make sure all of the tabs and grooves are matched. For example, the compound NaCl is shown in Figure 18-5.

Figure 18-5



After you have put together as many "atoms" as you can, make a table like the one below. Then write down the information about the "atoms" in each "compound" that you have made. Chemists put metals before non-metals in a formula. So list the metals on the left in your table and the non-metals on the right. Your metallic "atoms" have tabs, and your non-metallic "atoms" have grooves. Also remember that metals have a positive combining capacity, and non-metals have a negative combining capacity.

Use the information in your table to write the formula for each "compound" that you have made. If there is more than one atom of the same kind in a compound, you write the number of atoms of that element to the right and slightly below the symbol. ★

element	**combining capacity**	**number of atoms**	**element**	**combining capacity**	**number of atoms**	**compound**
Na	+1	1	Cl	−1	1	NaCl
?	?	?	?	?	?	?

Did You Get the Point?

Atoms share electrons to form molecules.

A chemical formula shows the composition of a substance.

The combining capacity tells the number of electrons that an element loses, gains, or shares.

Metals lose electrons and have positive combining capacities. Non-metals gain or share electrons and have negative combining capacities.

What Have You Learned?

1. How many oxygen atoms combine with a sulfur atom to form a molecule of SO_2?

2. Sodium (Na) has a combining capacity of +1 and oxygen (O) has a combining capacity of −2. What is the formula for sodium oxide?

The Periodic Table

18-5 Organizing what you know about the elements

You have learned about some elements and compounds. But there are more than 100 elements and more than a million compounds. Chemists have learned a lot about them over the years. But chemists do more than make observations and keep records. They look for patterns. They put facts together to form ideas. They predict how elements may react. But to get at the facts easily, all of this information has to be organized. One way that chemists use to organize the facts is a table called the periodic table.

What do you know about the different elements? How did you classify elements in Chapter 17? Now you know more about how the structure of an atom affects the way that element reacts.

Figure 18-6

Column VIII

2 He
10 Ne
18 Ar

The complete table of all the elements is called the periodic table. The elements are arranged according to their atomic numbers. Elements with similar properties are lined up in the vertical columns. Helium (He), neon (Ne), argon (Ar), and the other noble gases are grouped in Column VIII (Figure 18-6). They make up one chemical family. The elements in this family are chemically stable. That is, none of them are chemically active.

Figure 18-7

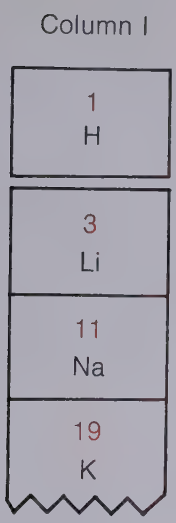
Column I

3 Li
11 Na
19 K

Three very active metals, lithium (Li), sodium (Na), and potassium (K), are in Column I (Figure 18-7). These elements have a combining capacity of +1 because the atoms of these elements lose their outermost electron in forming compounds. The ions that form have the same number of electrons as the atoms of the closest noble gas in the periodic table. What are some other properties of the metals in Column I?

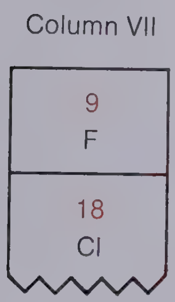
Hydrogen is placed in Column I because it has only one electron and has a +1 combining capacity. Active metals can take the place of hydrogen in certain compounds. For example, hydrogen is released from water when potassium is put in water. You found that hydrogen is released from hydrochloric acid by adding a piece of magnesium to the acid. (See Section 17-1.)

Figure 18-8



Hydrogen is different from the other elements in Column I. Figure 18-8 shows H set apart from the chemical family in Column I. Hydrogen atoms share electrons with other atoms to form molecules. But the metals in Column I always form positive ions. So hydrogen is an unusual member of Column I.

Figure 18-9



Another group, the halogens, are in Column VII (Figure 18-9). Fluorine (F), and chlorine (Cl), as well as the other halogens, are very active non-metals. Atoms of halogens react by gaining or sharing electrons. The elements in this group have a combining capacity of −1.

The periodic table is also divided into rows. Going from left to right across a row, the number of electrons in each kind of atom increases. The number of outermost electrons that an atom has is the same as the column number. Let's look at Row 3 in Figure 18-10. Sodium (Na) is a very active metal. Its atoms have a single outermost electron that they lose in reactions. Magnesium (Mg) is an active metal, but less active than sodium. Magnesium atoms have 2 outermost electrons that they lose in reactions. The next element, in Column III, is aluminum (Al). Aluminum is a less active metal than magnesium and loses 3 electrons in forming compounds.

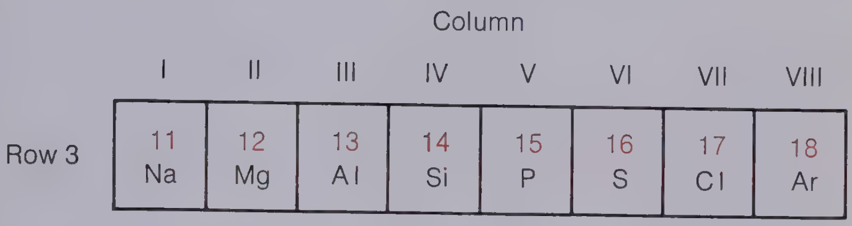


Figure 18-10

Silicon (Si), in column IV, is a non-metal and not very active. It is used in transistors. Quartz is an oxide of silicon. Phosphorus (P), in column V, is an active non-metal. One form catches fire if it is exposed to air. Phosphorus compounds are used in fertilizers.

Sulfur (S), in Column VI, has 6 outermost electrons. It is an active non-metal and has a −2 combining capacity. Chlorine (Cl) is a very active non-metal that gains an electron or shares electrons to form molecules and compounds. Its combining capacity is −1. Row 3 is completed by argon (Ar), a noble gas.

The properties of the elements in a row go from a very active metal to a very active non-metal, and then to a noble gas. In going across a row from left to right, the elements become less metallic and more non-metallic. The row ends with a chemically stable element.

The table in Figure 18-11 shows the first twenty elements. You know something about the activity of these elements. You can use this information to make some good guesses about the properties of other elements and their compounds. This is just what chemists do.

Appendix 2 is a periodic table of all the known elements.

Figure 18-11

	Column							
	I	II	III	IV	V	VI	VII	VIII
Row 1	1 H							2 He
Row 2	3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
Row 3	11 Na	12 mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
Row 4	19 K	20 Ca						

Did You Get the Point?

The periodic table is an arrangement of all the elements according to their atomic numbers.

Vertical columns of the periodic table have elements with similar chemical properties.

The number of outermost electrons that an atom has is the same as the column number.

Going from left to right across a row, the properties of the elements go from a very active metal to a very active non-metal. Each row ends with a noble gas.

What Have You Learned?

1. Find lithium (Li) and beryllium (Be) in the table in Figure 18-11. Which metal is more active, Li or Be?

2. Sodium (Na) and chlorine (Cl) react explosively. What do you think happens when a piece of potassium (K) is put in some chlorine gas?

SKULLDUGGERY

1. Your teacher will give you a copy of the school lunch menus for the last few weeks. Study them carefully. Make a list of those meals that appear more than once. How often do they appear? Predict some dishes you think might be prepared for next week. When the menu is published, check your predictions.

2. The word "composition" was used in its chemical sense in this chapter. But we use the word in everyday language. What is the composition of the class? You might think in terms of number of students with a particular hair color or a particular age group. Think of other ways to define the composition of the class.

FOR FURTHER READING

Hyde, Margaret O. *Atoms Today and Tomorrow,* 4th edition. New York: McGraw-Hill, Inc., 1970. Principles of atomic energy, present and potential uses, and possible dangers.

Smith, Richard Furnald. *Chemistry for the Million.* New York: Charles Scribner's Sons, 1972. Families of elements and historical development of chemistry.

WHAT'S NEXT?

In this chapter you have learned a lot about the structure of atoms and how atoms combine to form molecules. Now you are going to study some reactions that involve special kinds of compounds.

N
TIC

Chapter 19

Acids, Bases, and Salts

We use words to communicate with each other, but sometimes the communication goes wrong. The words we put together often mean one thing to us and something else entirely to another person. In a way, the English language is really a lot of different languages. A word or a group of words can mean different things at different times.

Take the word "base" for example. To the players in the photo, a base can be found at each corner of a baseball diamond. You can run bases, guard bases, and even steal bases. But to a mathematician, *base* means something different. It would be pretty hard to steal the base of a triangle. And a chemist would not think about triangles or Yankee Stadium when the subject of bases was mentioned.

The problem is to sort out ordinary language from special language. In the special language of chemistry, many ordinary words are used with special meanings. Chemists have defined those meanings carefully and always use them in the same way when they are discussing chemistry. In this way, there is little room for doubt about what they mean.

It's always a good idea to choose your words carefully, but in science it's absolutely basic.

Some Properties of Acids and Bases

19-1 Liquids conduct electricity

In Chapter 7 you learned that electric current in a wire is a stream of electrons. But without a complete path, there is no current. Also, you learned in Section 7-3 that some liquids conduct electricity and some do not. For example, distilled water and alcohol are poor conductors. But salt water is a good conductor.

Liquids that conduct electricity have many ions. So distilled water and alcohol must have very few ions, if any at all. And salt water must have a lot of ions. The ions in liquids are free to move around. And the electric current through a liquid results from the movement of ions.

Substances that form ions when they dissolve in water are said to **ionize.** Salt ionizes in water, but sugar doesn't. Compounds that ionize in water are called acids, bases, or salts.

Materials
materials to test, dry cell, lamp and socket, switch, wire, screwdriver

★ Make a table like the one in your book.

material	brightness of light	kind of conductor		
		good	weak	poor
tap water	faint			✓
distilled water	none			✓

Test the materials as you did in Section 7-3. Look back at Figure 7-7 to find out how to use your tester. Write down how brightly the light glows and check off each material as a "good," "weak," or "poor" conductor. ★

The liquids that you have called "good" and "weak" conductors contain acids, bases, or salts. Acids, bases, and salts form ions in water. But how are these compounds different? You will find out by doing the experiments in this chapter.

19-2 Acids have special properties

All the substances listed below are acids:

HCl	hydrochloric acid	H_3BO_3	boric acid
HNO_3	nitric acid	H_2CO_3	carbonic acid
H_2SO_4	sulfuric acid	CH_3COOH	acetic acid

Most people think that all acids are dangerous. This is not true. Many acids are dangerous but many acids are not. For instance, you can make a salad taste great by putting oil and vinegar on it. Vinegar contains acetic acid. Lemonade contains citric acid. In fact, many foods get their taste from the acids in them. A few foods that contain acids are shown in Figure 19-1.

Figure 19-1 *All these foods contain some acid.*

The acids that we use in chemistry are dissolved in water. For instance, hydrochloric acid (HCl) is formed by bubbling hydrogen chloride gas into water. As the gas is dissolved, the water separates it into hydrogen ions, H^+, and chloride ions, Cl^-. Water tends to separate all the hydrogen chloride molecules into ions. As the ions move around in the water, the hydrogen ions became attached to water molecules, forming H_3O^+. The mixture of hydrogen chloride and water is an acidic solution because it contains a lot of H_3O^+ ions.

The simplest way to represent the reaction of hydrogen chloride and water is

water + hydrogen chloride = H_3O^+ + chloride ion
(water with a hydrogen ion
attached to it)

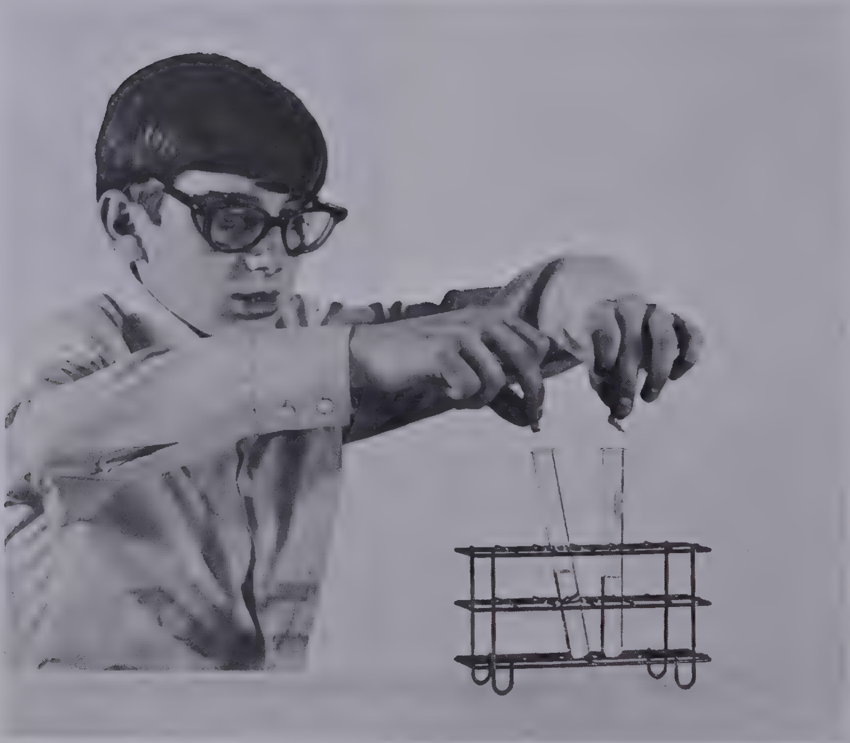
The strength of an acid depends on how freely it forms ions, or ionizes, in water. HCl is a strong acid because it ionizes freely in water. A weak acid ionizes only slightly. Most of the particles of a strong acid form ions, but most of the particles of a weak acid remain as molecules.

Materials
two test tubes, test tube rack, dilute hydrochloric acid, dilute acetic acid (vinegar), two small pieces of zinc

★ Pour dilute hydrochloric acid into a test tube until it is about one-third full. Set it in the test tube rack. Pour the same amount of dilute acetic acid into another test tube and put it in the rack.

Drop the same size piece of zinc into each test tube, as in Figure 19-2. Is the amount of bubbling the same in both test tubes? What gas is being released? Look up how well the two acids conduct electricity. Which acid contains more

Figure 19-2 *Wear safety glasses when you put the zinc into the test tube.*



ions? Which one is the stronger acid? What are some properties of both of these acids? How are the acids different? ★

Do not confuse the terms *strong* and *weak* with the terms *dilute* and *concentrated.* "Strong" and "weak" tell you how freely an acid ionizes. "Concentrated" and "dilute" tell you whether water has been added. The frozen juice you buy at the store is concentrated. When you mix it with water, you dilute it.

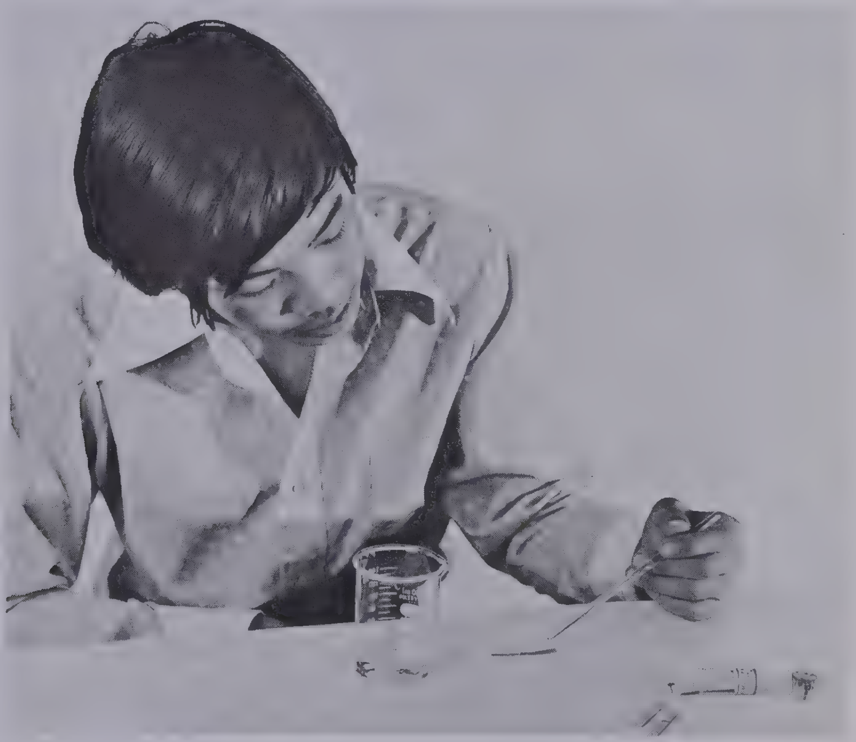
You already know another property of acids. Lemonade tastes sour if it doesn't have enough sugar. And vinegar has a sour taste also. Lemon juice is sour because it contains citric acid. And vinegar has acetic acid in it.

Chemists do not test chemicals by tasting them. That could be dangerous. It is necessary to have a more scientific method for identifying acids.

Materials
litmus paper, dilute hydrochloric acid, dilute acetic acid, stirring rod

★ Wash a stirring rod. Dip the rod into dilute hydrochloric acid and touch a piece of red and a piece of blue litmus paper with the rod as shown in Figure 19-3. Wash the stirring rod again.

Figure 19-3 *Unless you know you are testing a weak acid, use a stirring rod.*



Dip one end of another piece of blue litmus paper into some vinegar (acetic acid) as shown in Figure 19-4. Test the vinegar with another piece of red litmus paper also. Write down your observations. ★

Litmus is an indicator. An **indicator** changes color in the presence of acids or bases.

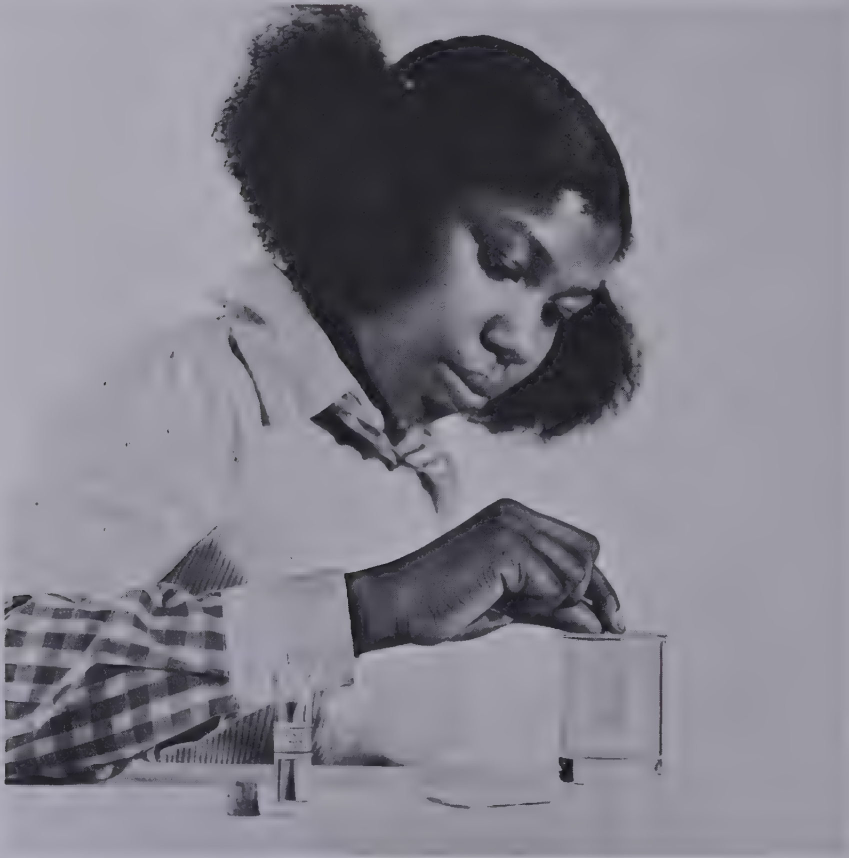


Figure 19-4 *To test a weak acid, dip the litmus paper into it.*

19-3 Bases have special properties

Look carefully at this list of compounds:

KOH	potassium hydroxide
NaOH	sodium hydroxide
NH_4OH	ammonium hydroxide
$Ca(OH)_2$	calcium hydroxide
$Ba(OH)_2$	barium hydroxide
$Mg(OH)_2$	magnesium hydroxide

All of these compounds are bases. Look at the formulas. Can you see a pattern, something that they all have in common? The pattern is important. It tells us what a base is.

Lye, a material that is used to clean out clogged drains, is a strong base. Lye contains NaOH or KOH. Using lye can be dangerous because getting it on your skin causes serious burns. Many household materials, like the ones in Figure 19-5, are also bases.

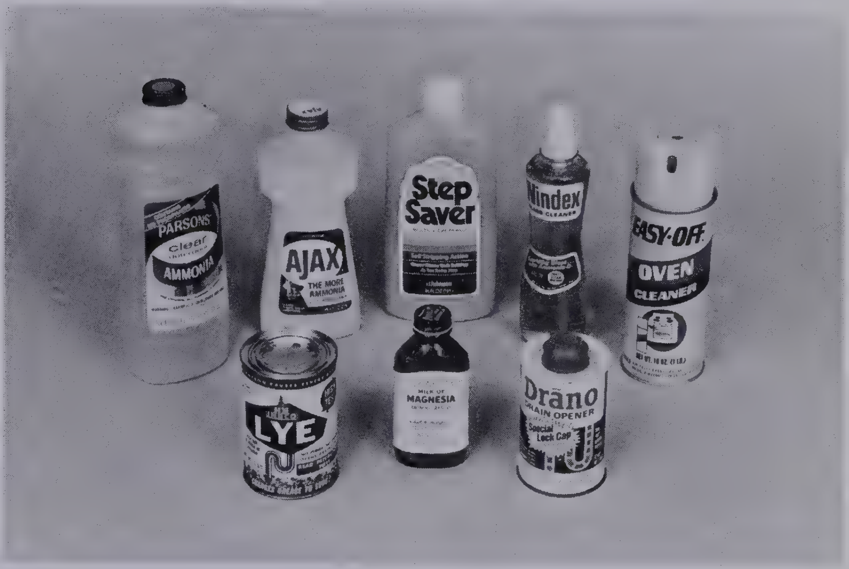


Figure 19-5 *All of these household materials are bases. What are most of them used for?*

When a base is put in water, it ionizes. Metallic ions and hydroxide ions are formed. A hydroxide ion (OH^-) is a combination of oxygen and hydrogen that usually holds together in chemical reactions. The minus sign tells you that it is a negative ion. As with acids, strong bases ionize freely in water.

$$\text{sodium hydroxide} = \text{sodium ions} + \text{hydroxide ions}$$

Weak bases ionize only slightly. Ammonium hydroxide, household ammonia, is a weak base. It has the sharp, unpleasant smell of ammonia gas. In fact, household ammonia is made by dissolving ammonia gas in water. The resulting solution is called basic because it contains a lot of free hydroxide ions.

Look at the formula of ammonium hydroxide. Instead of a metal as the other bases have, ammonium hydroxide has an ammonium ion (NH_4^+). The ammonium ion acts like a metal. Ammonium ions and hydroxide ions are polyatomic (pol-ee-uh-TOM-ik) ions. A **polyatomic ion** is a charged chemical unit made of two or more different atoms that usually stay together in reactions. The word *poly* means ''many.'' Like other ions, a polyatomic ion has a positive or a negative charge.

Materials
test tube, red and blue litmus paper, detergent, sodium hydroxide solution, calcium hydroxide solution, stirring rod

★ How can you tell if a solution is basic? Put a small amount of liquid detergent into a test tube. Half fill the test tube with water. Dip one end of a piece of red litmus paper into the solution. Then dip a piece of blue litmus paper into the soap solution. Write down your observations.

With strong acids and bases, you should not dip the litmus paper into the solution. Instead use a stirring rod as shown in Figure 19-3.

Wash a stirring rod. Dip the rod into sodium hydroxide solution and touch a piece of red and a piece of blue litmus paper with it. Rinse the rod and write down your observations. Test calcium hydroxide in the same way. ★

Did You Get the Point?

Liquids that conduct electricity have ions.

Acids react with water to form ions. Acids react with metals to form hydrogen gas. Strong acids ionize more freely than weak acids. Some foods taste sour because of acids.

Bases form hydroxide ions, OH^-, in solutions.

A polyatomic ion is a group of atoms that usually stays together in reactions. There are metallic polyatomic ions (positive charge) and non-metallic polyatomic ions (negative charge).

What Have You Learned?

1. Is vinegar a strong or a weak acid? Give a reason for your answer.

2. Can you make a strong base weak by diluting it with water? Why or why not?

Testing for Acids and Bases

19-4 Indicators

You may be surprised to find out how many common materials are indicators like litmus.

Materials
test tube rack, test tubes, tea, dilute solutions of ammonium hydroxide, sodium hydroxide, acetic acid, hydrochloric acid

★ Pour enough tea into five test tubes to half fill each one. Add a few drops of acetic acid to the first test tube. Write down what happens in your notebook. Add a few drops of ammonium hydroxide to the second test tube. What happens this time? Now add a few drops of dilute hydrochloric acid to the third test tube and write down what happens. Finally, add a few drops of sodium hydroxide solution to the fourth test tube. Is the color change what you expected? The fifth test tube, containing only tea, is your control. Compare the colors of the mixtures in the first four test tubes with the color of tea. What is the "tea test" for acids? for bases? ★

Tea contains a weak acid, tannic acid. Acids and bases affect the color of tannic acid, so it makes a good indicator. Most other indicators are weak acids also.

Materials
litmus paper, filter paper, table mustard, wooden splint, dilute boric acid, borax, dilute hydrochloric acid, test tube, rack, funnel, beaker, asbestos pad, stand, burner

★ Cut some filter paper into four or five small strips. Coat both sides of the pieces of paper with mustard as in Figure 19-6. Then wash off the mustard and allow the strips to dry.

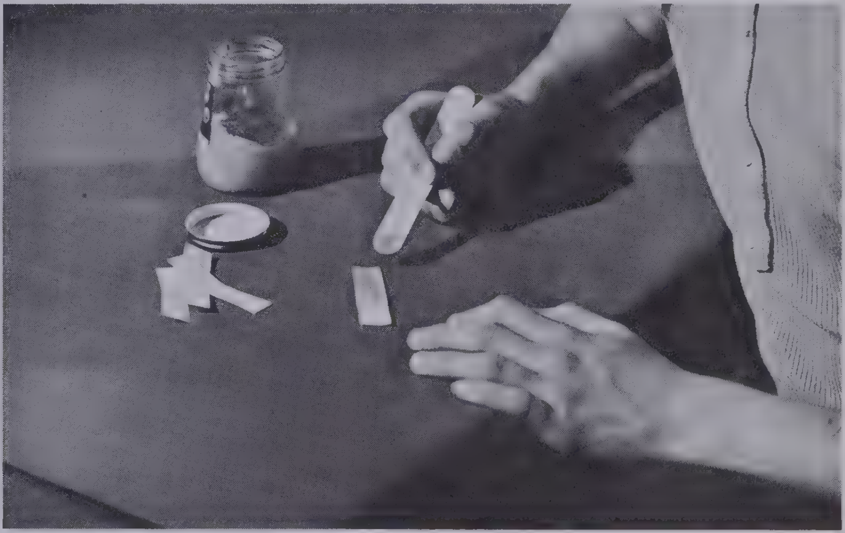


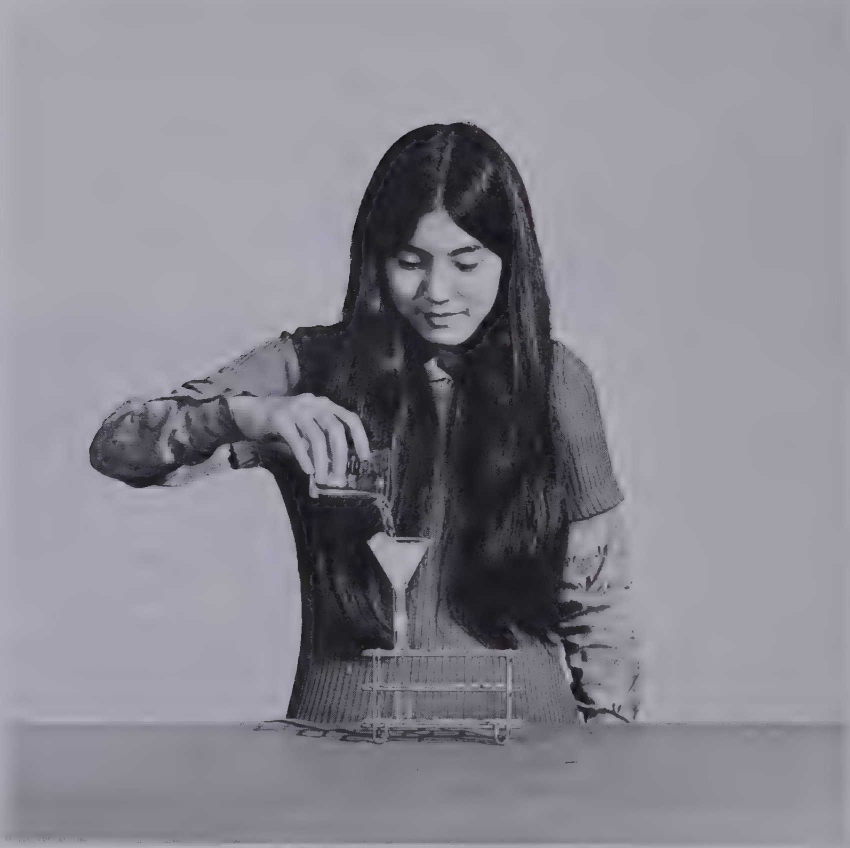
Figure 19-6 *Apply a thin even coat of mustard to both sides of the filter paper.*

Dip a strip of the dry mustard paper in a solution of boric acid. What is the color of the test paper in the presence of boric acid? Dip a strip of the paper in some dilute hydrochloric acid. Is there any color change?

You can make boric acid from borax, which is found in certain household cleaners. Put a teaspoon of borax in a small beaker. Add about 20 ml of dilute hydrochloric acid. With constant stirring, heat the borax and hydrochloric acid until all of the borax dissolves. Set the solution aside to cool.

Stir the cool mixture and filter it into a test tube. Pour off the liquid, which is salt water, into the sink. Rinse the test tube and the stem of the funnel. Pour a little warm water over the white solid in the funnel as in Figure 19-7 and collect the liquid in the test tube. Test the liquid with litmus paper and then test it with your boric acid test paper. Does the liquid contain an acid? Is it boric acid?★

Figure 19-7



Beets and red cabbage also contain materials that can be used as indicators.

Materials
test tube rack, 4 test tubes, beet juice or red cabbage juice, dilute solutions of ammonium hydroxide, sodium hydroxide, acetic acid, hydrochloric acid

★ Put a few drops of beet juice or red cabbage juice in several solutions. How do acidic solutions affect the color? What effect do basic solutions have? ★

19-5 How acidic or basic is it?

In many ways acids and bases are opposites. Acids in water release hydrogen ions and non-metallic ions. Bases form metallic ions (except for NH_4^+) and hydroxide ions. The more acidic a material is, the less basic it is. Also, you know that acids and bases have different effects on the colors of indicators.

Chemists rate how acid or basic a solution is by using a scale of numbers from 0 to 14. These are called **pH numbers.**

Materials
watch glasses, pH paper, liquid indicators, liquids and solids to test

★ Write the names of the indicators you have in a table like the one in your book.

material	colors of indicators					approximate pH of material	pH from pH paper
	orange IV	methyl orange	bromthymol blue	alizarin yellow	phenolphthalein		
distilled water	?	?	?	?	?	?	?

Pour a small amount of distilled water into clean watch glasses. Then add a few drops of a different indicator to each watch glass. Write down the colors of the mixtures.

Wash the watch glasses thoroughly and add a small amount of another liquid to each one. Again add a few drops of the indicators and write down your observations. Wash the watch glasses. Repeat this procedure for all of the liquids. Wash the watch glasses thoroughly between tests.

Put a drop of an indicator on each piece of solid material. Write down the results in your table. Test the other materials with the indicators and write down your results.

Now figure out the approximate pH of each material. Figure 19-8 tells the colors of several indicators at different pH numbers.

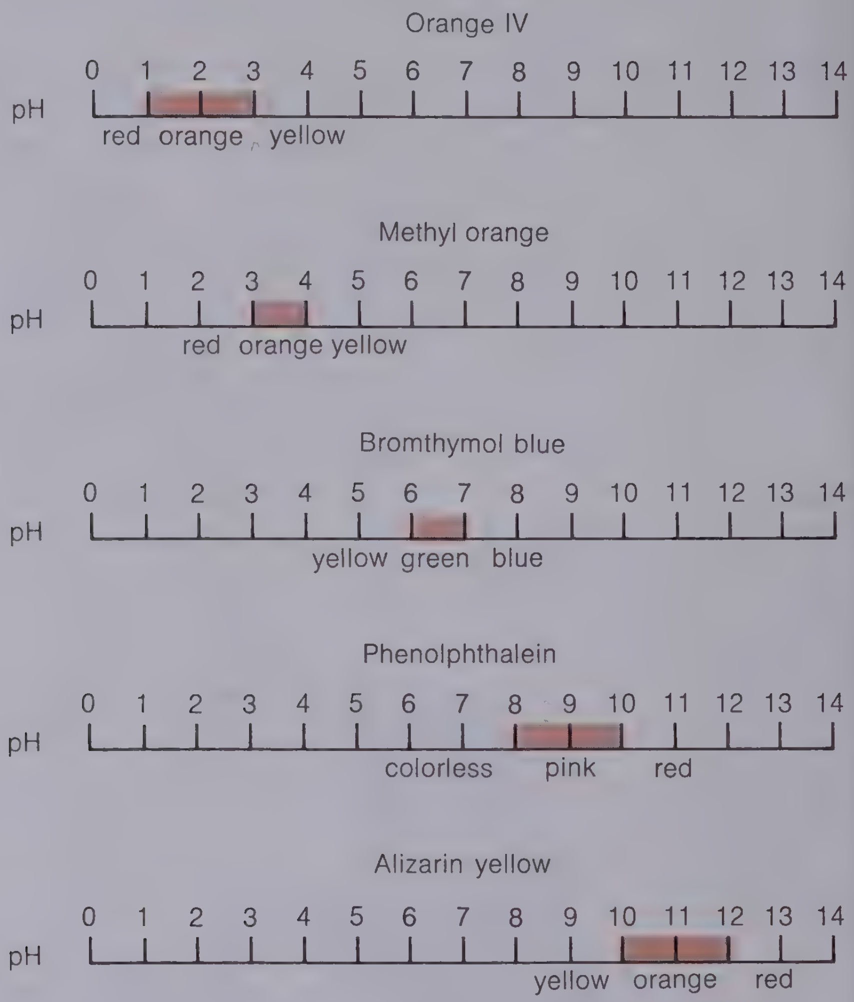


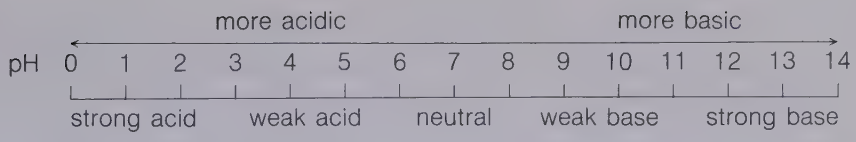
Figure 19-8 *Acid-base indicators change color at certain pH numbers.*

What problems do you have in deciding the different pH numbers? Check your decisions by testing all the materials with pH paper. Write these numbers in your table. Which material has the highest pH number? the lowest pH number?

Look at your table of pH numbers and compare the numbers with the scale in Figure 19-9. The lower the number, the more acidic the material is.

What are the pH numbers of hydrochloric acid and boric acid? What are some other acid materials in your table?

Figure 19-9



What is the pH of pure water? It is neutral—neither acidic nor basic. Values above 7 are for bases. The higher the number, the stronger the base. Which materials in your table are strong bases? Which ones are weak bases? ★

Did You Get the Point?

Indicators tell how acidic or basic a material is.

A pH number is used to rate how acidic or basic a material is.

Acidic solutions have pH numbers below 7. Basic solutions have pH numbers above 7.

What Have You Learned?

Bring some materials from home, such as cleansers and cooking materials. Test them to see which are acids and which are bases. And try to find the approximate pH of each one.

Neutralization

19-6 What happens when you mix an acid and a base?

> In case of accidental swallowing, drink lemon juice or vinegar and call a doctor.

Materials
white paper, watch glass, dilute hydrochloric acid, dilute sodium hydroxide, medicine dropper, stirring rod, phenolphthalein, beaker, water, stand, wire gauze, burner

You have probably read this suggestion on the label of a household cleaner or laundry detergent. Find out what happens when you mix an acid and a base.

★ Put a clean watch glass on a piece of white paper. Pour a small amount of dilute hydrochloric acid into the watch glass. Test the pH of the acid with pH paper and add a drop of phenolphthalein solution. Add sodium hydroxide solution with a dropper, one drop at a time. Use a stirring rod to stir the mixture in the watch glass after each drop is added. Do not stir with the dropper.

When a faint pink color appears and does not fade, stop adding sodium hydroxide. Test the pH of the mixture. What has adding a base done to the acid?

Put the watch glass on a beaker, half-filled with water, as shown in Figure 19-10. Heat the beaker until the liquid in the watch glass has evaporated. Look carefully at the solid on the watch glass. ★

The solid on the watch glass is table salt. The reaction is

hydrochloric acid + sodium hydroxide = salt + water

If you use formulas instead of words, the equation becomes a **chemical equation.** The chemical equation for the reaction of hydrochloric acid and sodium hydroxide is

$$\mathrm{HCl + NaOH = NaCl + HOH}$$

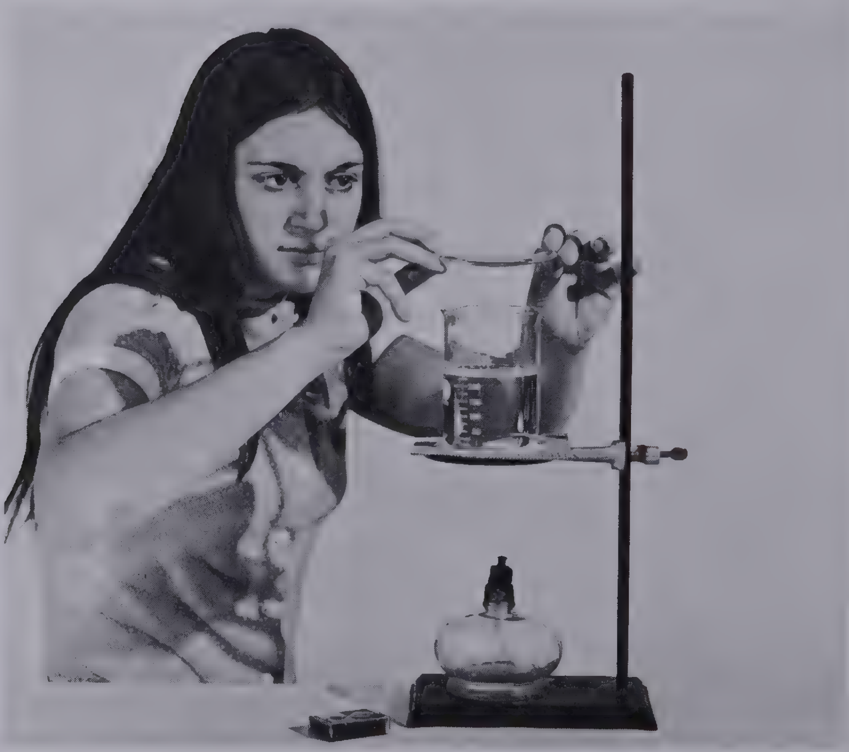


Figure 19-10 *Why not heat the watch glass directly over the flame?*

When HCl and NaOH react with each other, the H^+ from the acid and the OH^- from the base combine to form molecules of water. The formula for water (HOH) is written in a different way to help you understand the reaction. This kind of reaction is called neutralization. **Neutralization** is the reaction of an acid and a base that forms a salt and water. A **salt** is any compound that contains positive ions other than hydrogen and negative ions other than hydroxide.

A neutralization reaction can be shown as

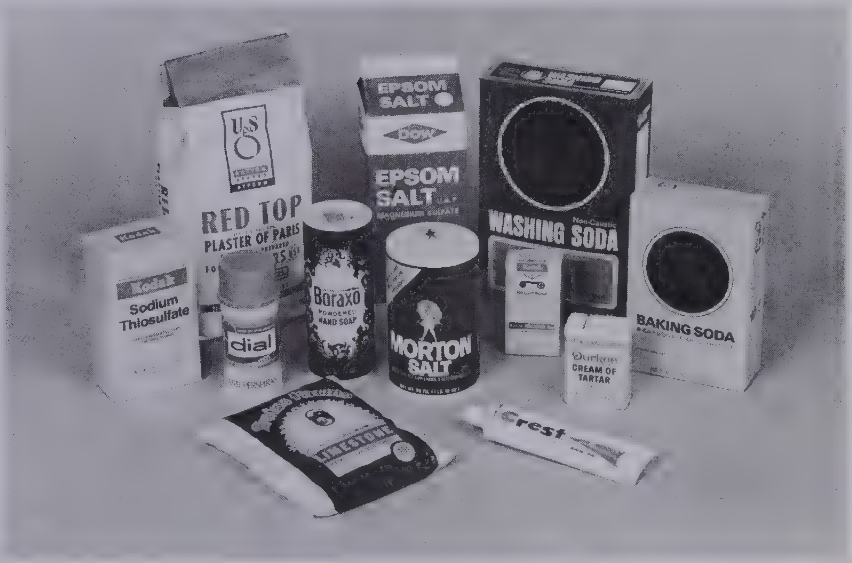
$$\text{acid} + \text{base} = \text{salt} + \text{water}$$

Now you should be able to figure out how drinking lemon juice would help after swallowing a household cleaner.

19-7 Many common materials contain salts

There are many different kinds of salts. A few materials that contain salts are shown in Figure 19-11. Since salts are formed by neutralization, would you expect salt solutions to be neutral? Look in the table of pH numbers that you made in Section 19-5. Do you think that any of these materials contain salts? What are the pH numbers of some of these materials?

Figure 19-11 *Find materials like these in your home. What salts do they contain?*



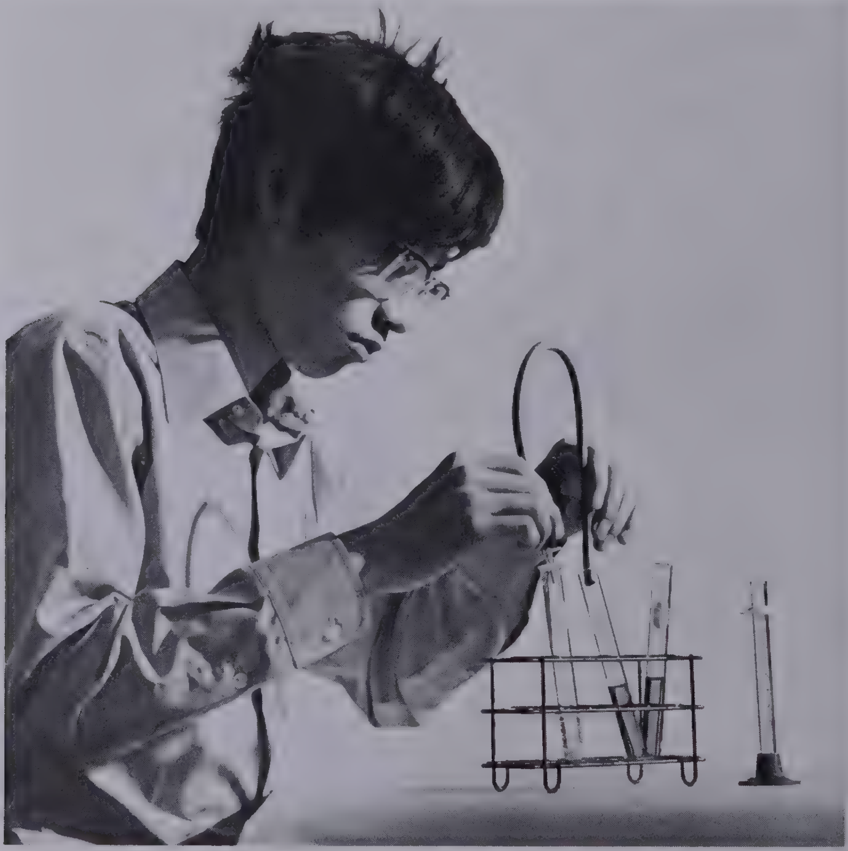
Materials
watch glass, pH paper, liquid indicators, materials to test

★ Test the materials with the indicators as you did in Section 19-5. Add the results to your table. ★

You know that distilled water is a poor conductor of electric current. So you might guess that distilled water has no ions. But this is untrue. Even pure water is slightly ionized, but so slightly that only special instruments could detect it. Some of the water molecules form H_3O^+ and OH^-. In pure water the numbers of H_3O^+ and OH^- are equal, so pure water is neutral. A neutral compound is neither acidic nor basic.

Some salts react with water molecules in a way that is the opposite of neutralization. These salts form solutions that have unequal numbers of H_3O^+ and OH^-. They are acidic or basic.

Figure 19-12 *Be sure to rinse off the end of the rubber tubing before you put it into the limewater.*



Materials
baking soda, vinegar, litmus paper, 3 test tubes, limewater, graduate, bromthymol blue, one-hole rubber stopper, glass tubing, rubber tubing

★ Put a teaspoonful of baking soda into a test tube and add a small amount of water. Test the mixture with litmus paper. Put the test tube in a rack.

Put a small amount of water into another test tube and some limewater into a third test tube. Add a drop of bromthymol blue to the water and to the limewater. Set the test tubes in a rack. What happened? Write down your observations.

Measure out 3 or 4 ml of vinegar. Pour the vinegar into the baking soda solution and quickly insert the rubber stopper, as shown in Figure 19-12. Put the loose end of the rubber tubing into the test tube containing water and the indicator. After a few seconds remove the tubing, rinse off the end with clean water, and put it in the limewater mixture. Write down your observations. What gas causes a precipitate to form in limewater? Test the acidity of the products in the stoppered test tube. If it is still acidic, add a little more baking soda. Do this until the mixture is neutral. Is baking soda (sodium bicarbonate) a neutral salt? ★

Calcium carbonate is one of the most common salts in the world. It is found in the shells of sea animals like clams. It is found in limestone, which is made of the shells of dead shellfish. Chalk contains a lot of calcium carbonate.

Materials
a small piece of chalk, hydrochloric acid, beaker, watch glass, asbestos pad, ring, ringstand, burner, litmus paper, stirring rod

★ Put a small piece of chalk in a beaker and add a small amount of water. Slowly add dilute hydrochloric acid, one drop at a time. Stir the mixture after each addition of acid. Continue adding acid until the mixture is neutral. How do you know when the mixture is neutral?

Pour a small amount of the mixture on a watch glass. Put the watch glass on a half-filled beaker of water. Heat the beaker until the watch glass is dry. Look at the solid on the watch glass. Write down your observations. Set it aside and look at it the next day. ★

Did You Get the Point?

When an acid and a base react, a salt and water are formed.

Salts are made of positive ions other than hydrogen ions, and negative ions other than hydroxide ions.

Some salts form neutral solutions, and others form acidic or basic solutions.

What Have You Learned?

1. When KOH and HCl react, what salt is formed?

2. Which of the following are salts?

$Ca(OH)_2$	NH_4Cl	HOH
H_3PO_4	Na_2CO_3	CH_3COOH

3. Paul did an amazing demonstration at the school rally before a basketball game. He had two bottles of colored liquids, one red and the other yellow. These were the school colors of the other team. Paul added another liquid to each of the bottles. He called this liquid "school spirit." Adding "school spirit" changed the red liquid to orange and the yellow liquid to blue. Blue and orange were his school colors. Use the information in Figure 19-13 and the table you made in Section 19-5 to figure out Paul's trick. What liquids and indicators did he probably use?

Figure 19-13

liquids	indigo carmine	bromthymol blue	litmus	methyl orange	methyl violet
soda pop	blue	yellow	red	red	purple
borax solution	blue	blue	blue	orange	purple
lemon juice	blue	yellow	red	red	blue
milk	blue	green	pink	orange	purple
detergent	yellow	blue	blue	orange	purple

SKULLDUGGERY

1. An antacid helps to neutralize excess stomach acid. Look at the labels on several antacid remedies. What are some of the different ingredients? Are any of them chemicals that you have learned about in this chapter? Some antacids claim they can neutralize more stomach acid than other antacids can. Can you think of a way to test which antacid is best? If your plan is good enough, your teacher may let you try it in class.

2. Collect some rain water in a clean jar. Bring it to class and test it with acid-base indicators.

3. Get small amounts of soil from several different places. Label each one so you can keep track of where you collected them. At school, moisten the soil with distilled water and test each sample with pH paper.

FOR FURTHER READING

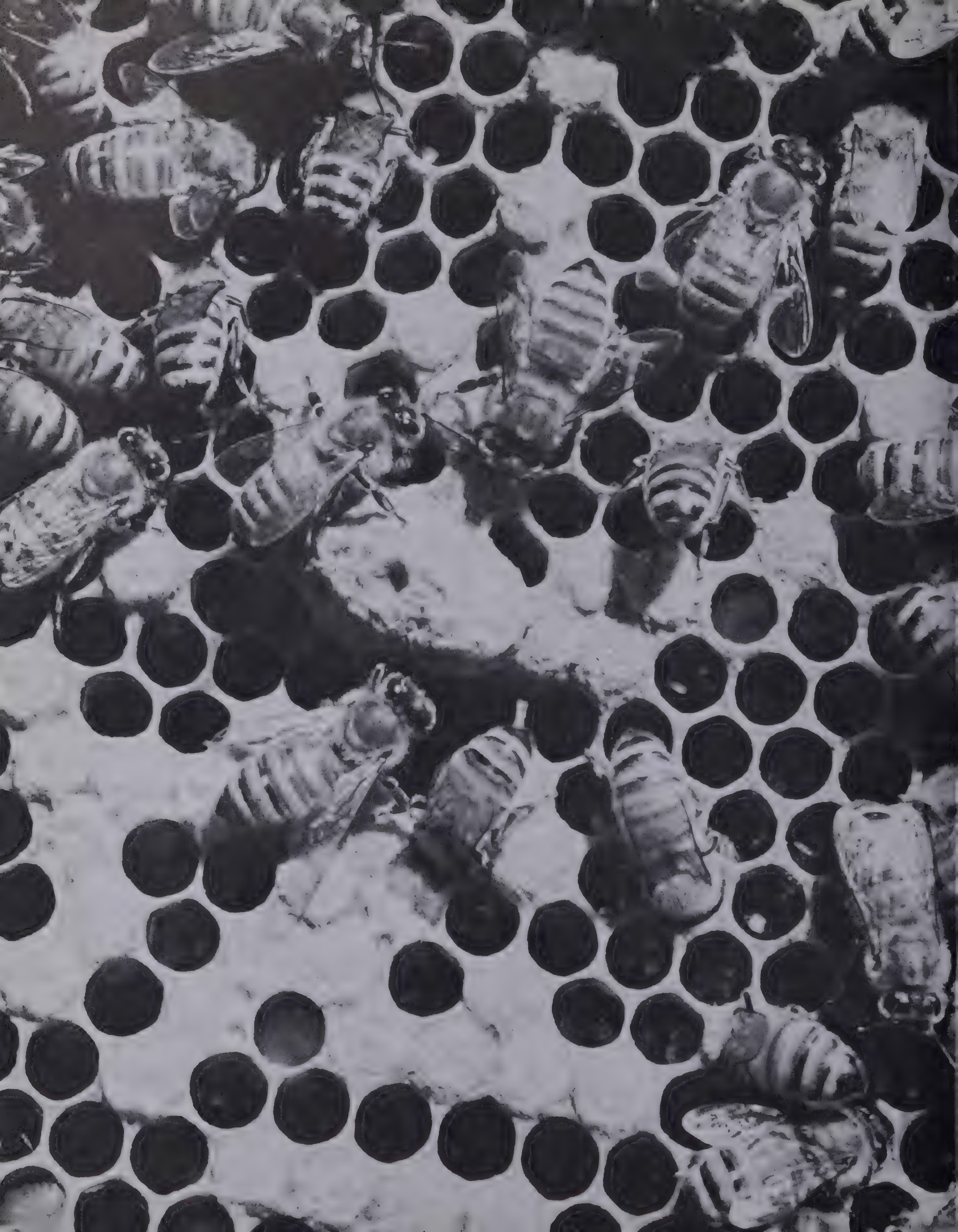
Goldin, Augusta R. *Salt.* New York: Crowell Collier and Macmillan, Inc., 1965. Chemistry of salt, its sources, uses, and importance.

Morgan, Alfred. *Adventures in Electrochemistry.* New York: Charles Scribner's Sons, 1959. Discusses electrolysis, batteries, refining of ores.

Stone, A. Harris, and Dale Ingmanson. *Crystals from the Sea: A Look at Salt.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1969. Covers relation of temperature to solubility, states of matter, buoyancy, specific gravity, and food preservation.

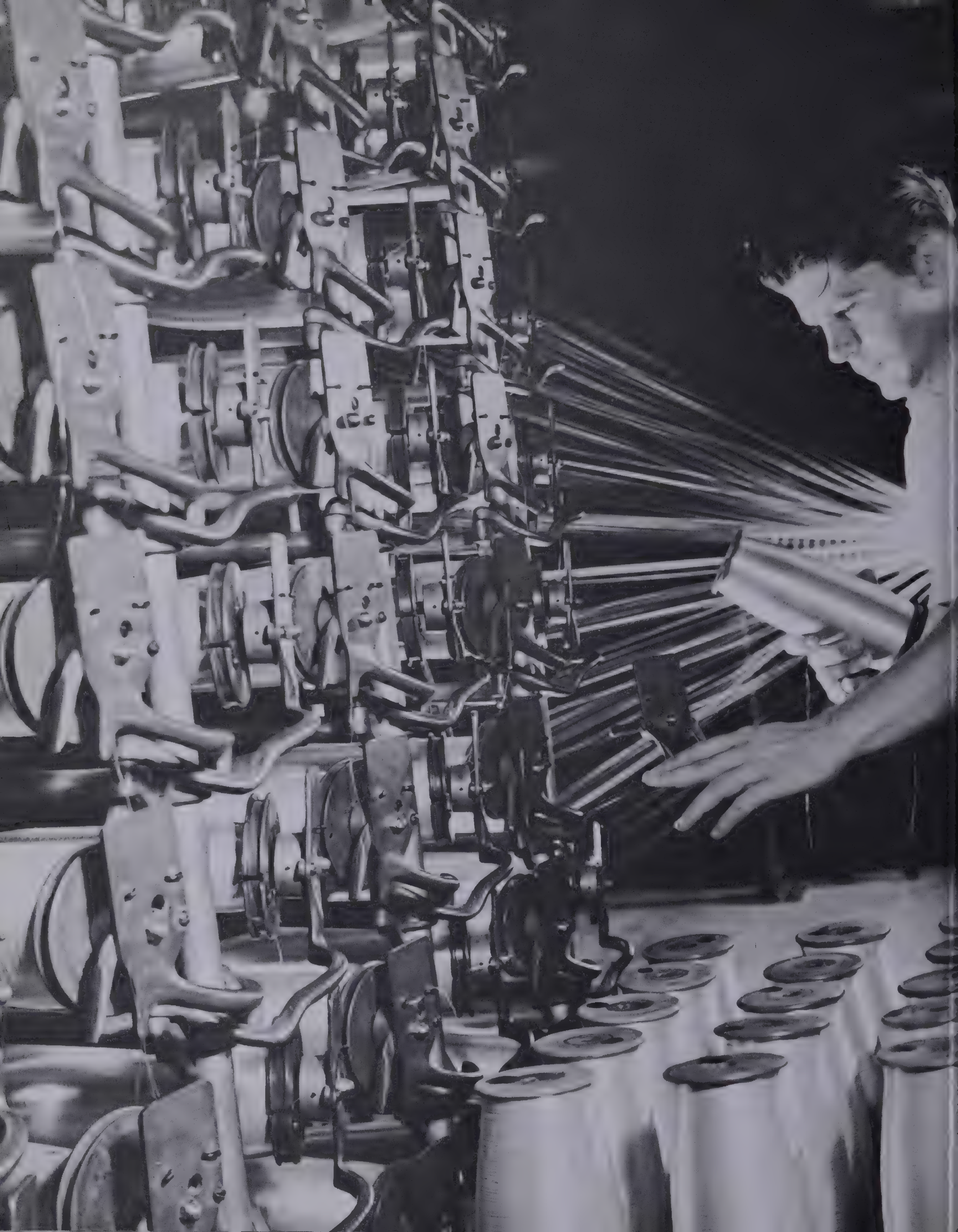
WHAT'S NEXT?

Carbon is a fairly abundant element. It is not very active. But there are many more carbon compounds than all the other kinds of compounds combined. In the next chapter, you will find out about ''the amazing carbon atom.''



Unit Seven

Chemistry and Life



Chapter 20

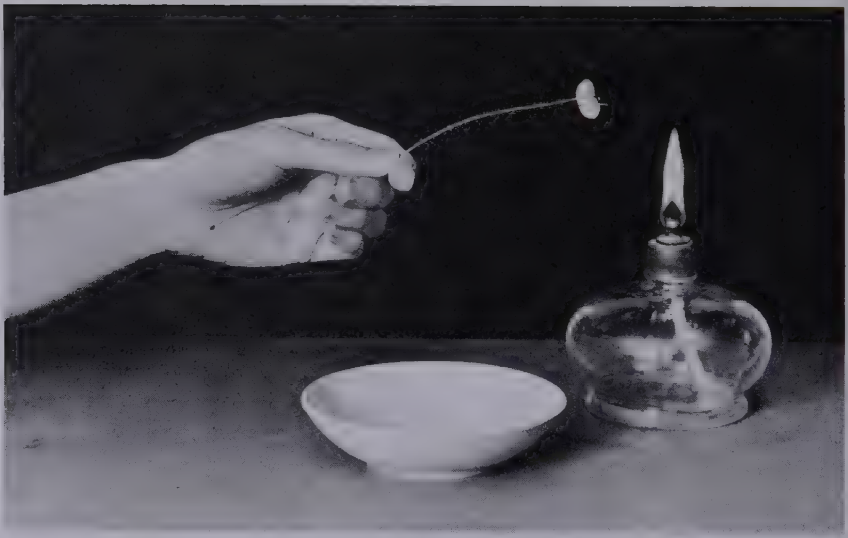
Carbon Compounds

The rayon being spun on this machine will become tire cord. But it could just as easily wind up in a shirt, a curtain, or the covering for a chair. Rayon is one of the most widely used fibers in the world. And it is just one of many man-made materials.

Until about a century ago, most of the materials people used were found in nature. But in the last hundred years, chemists have invented many new materials. Now, man-made materials play a part in almost everything we do.

Chemists have also learned to make many of the compounds found in nature more cheaply in their laboratories. They have been so successful that many people think of a chemical as something made in a laboratory. And they think that these ''chemicals'' are more dangerous or less healthful than natural materials. But substances made by a chemist have to obey the same chemical rules as all other materials. The Vitamin C made in a laboratory is exactly the same compound as the Vitamin C in an orange.

Figure 20-1



The Amazing Carbon Atom

20-1 Living things contain carbon compounds

What are living things made of? Why are they so much more complicated than iron or salt? Animals and plants are mostly water. (Think about the difference between a grape and a raisin.) But what about the rest of a plant or animal? Wood, fruit, and meat contain many substances. What do these substances have in common?

Materials
burner, wire, dish, peanut, wood, other materials from plants and animals

★ Light your burner. Wrap the end of the wire around the peanut as in Figure 20-1. Hold the peanut in the flame until it catches on fire. Remove the peanut from the flame and put it in the dish. Does the peanut stay lighted? Watch what happens. How does the peanut look? Do the same thing with the other materials. ★

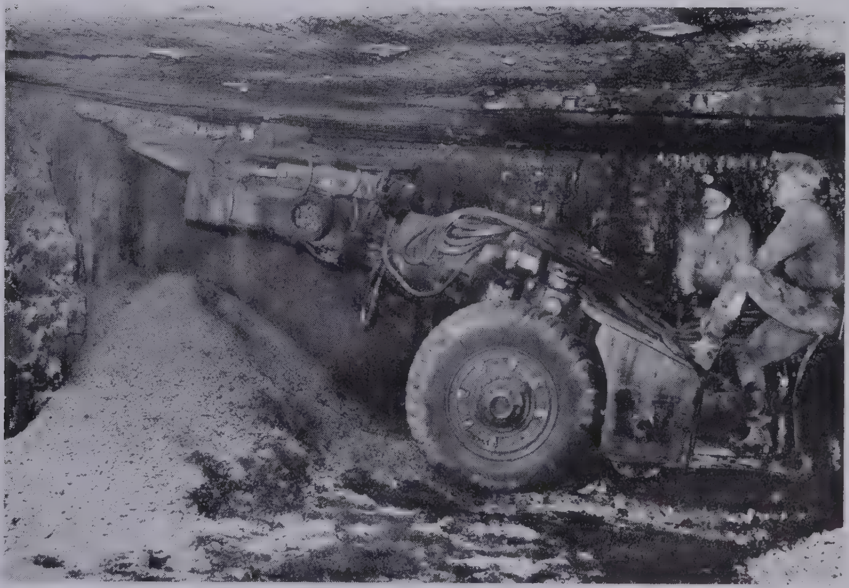
The black stuff that is left when plants or animals burn is carbon. Remember that carbon was left after you heated sugar in Section 13-5. Sugar is a carbon compound. It comes from plants. All living things contain carbon. Sugar, fat, protein, and many other substances found in animals and plants are carbon compounds.

Until about 150 years ago, scientists thought that carbon compounds could be made only by living things. So carbon compounds were called *organic,* meaning "from the organs." Then a scientist was able to make a carbon compound in the laboratory. Since then, a million carbon compounds have been made. They include plastics, detergents, and medicines. Some of these compounds can also be found in plants or animals, but others cannot. So now any compound containing carbon is called an **organic compound.**

Plants take energy from the sun. They make carbon compounds like sugar from carbon dioxide and water. These compounds store the energy. Plants use some of the energy themselves. When you eat and digest food from plants, the energy is released. You use the energy to live and to move. You also use some of the carbon compounds to build other compounds, to make muscles, skin, and the rest of your body.

20-2 Carbon compounds are used as fuels

The parts of plants that you do not eat also contain stored energy. When wood burns, it gives up energy as heat and light. If all the wood burns, it will leave only white ashes. Sometimes a material does not burn completely. This happens if there is not enough oxygen, or if there is too much water in the material. When a material does not burn completely, carbon may be left. This happened when you burned foods in Section 20-1.



Coal being cut in an underground mine. Later it will be loaded and taken to the surface.

Some plants are not eaten or burned. If plants are buried deep in the earth and left for millions of years under extreme pressure, they may turn into coal and oil. Coal is a mixture of carbon, carbon compounds, and other substances. Oil is a mixture of carbon compounds. These compounds are made only from hydrogen and carbon. Compounds made only from hydrogen and carbon are called **hydrocarbons** (HY-droh-kar-buns).

The lightest of the hydrocarbons is methane. The formula for methane is CH_4. Natural gas, which may be used for heating or cooking in your house, is mostly methane. Methane is one of the compounds in coal. It can be released by heating the coal.

Materials
cardboard box, soft coal, hammer, 3 test tubes, stand, burner, 1-hole stopper with glass tubing, 2-hole stopper with glass tubing, rubber tubing, pan, beaker, stopper, limewater

★ Put a lump of soft coal in a cardboard box. With a hammer, break the coal into pieces small enough to fit into the test tube. Clamp the test tube to the stand. Set up the rest of the equipment as shown in Figure 20-2. The beaker should have cold water in it. The upside-down test tube should be full of water.

Light the burner. Watch carefully what happens. What collects in the second test tube? This is a mixture of hydrocarbons that are solids or liquids at the temperature of the cold water. When the third test tube is full of gas, pull it out of the water and let the gas escape. What do you think this gas is? Fill the test tube with water again and put it back on the rubber tube in the pan.

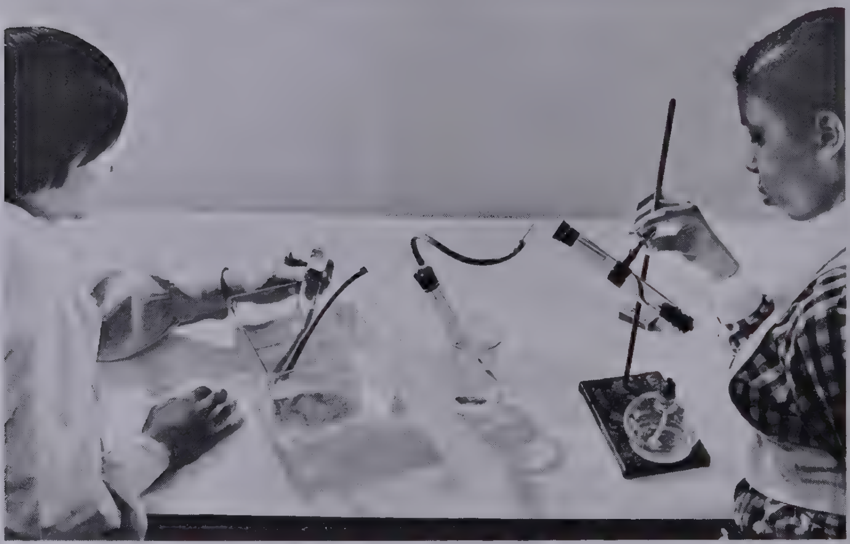


Figure 20-2 *You may want to test the mixture in the second test tube with litmus paper.*

When the third test tube fills with gas again, put out the burner and pull the stopper out of the second test tube. The gas in the third test tube is mostly methane. Your teacher will light the methane. Watch it burn. What color is the flame? Does it give off smoke? When the methane stops burning, look at the test tube. Do you see anything in it that was not there before? Pour a little limewater into the test tube. Put a stopper on the test tube and shake it. What happens? What substances are formed when methane burns? ★

20-3 Carbon is special

Thousands of compounds that do not contain carbon are known. But more than a million known compounds contain carbon. Carbon can form so many compounds because it can form very large molecules. Most of the molecules you have already studied are made from only two to six atoms. Carbon can form small molecules too, like CO_2 or CH_4. But carbon can also form very large molecules. One kind of starch has the formula $C_{216}H_{288}O_{144}$! Figure 20-3 shows the formulas for some other organic compounds.

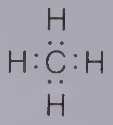
compound	formula
aspirin	$C_9H_8O_4$
caffeine	$C_8H_{10}N_4O_2$
cholesterol	$C_{27}H_{46}O$
DDT	$C_{14}H_9Cl_5$
nicotine	$C_{10}H_{14}N_2$
phenolphthalein	$C_{20}H_{14}O_4$
TNT	$C_7H_5N_3O_6$

Figure 20-3 *Some organic compounds.*

Carbon has four outer electrons. Carbon combines with other elements mainly by sharing electrons. A carbon atom with its four outer electrons can be written like this: $\cdot\overset{\cdot}{\underset{\cdot}{C}}\cdot$

To make methane, a carbon atom combines with four hydrogen atoms. What is the combining capacity of hydrogen? A hydrogen atom with its one electron can be written like this: $H\cdot$

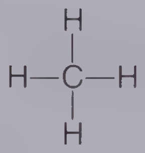
A carbon atom shares electrons with four hydrogen atoms to make a methane molecule. The methane molecule can be written like this:



$$\begin{array}{ccc} & H & \\ H & {:}\overset{\cdot\cdot}{\underset{\cdot\cdot}{C}}{:} & H \\ & H & \end{array}$$

Now the carbon atom has a share of eight outer electrons, like a neon atom. Each hydrogen atom has a share of two electrons, like a helium atom.

When two atoms share a pair of electrons, chemists often draw a line between the atoms instead of two dots. They would write methane like this:



$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & - & C & - & H \\ & & | & & \\ & & H & & \end{array}$$

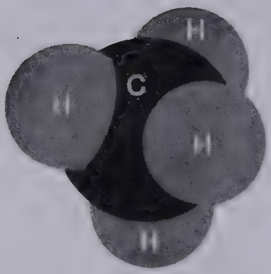
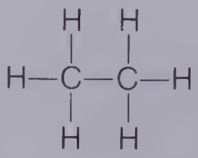


Figure 20-4 *A model of a methane molecule.*

Either of these formulas tells you more about methane than the ordinary formula, CH_4. A formula that shows how the atoms are connected is called a **structural formula.**

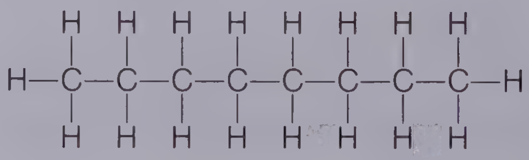
Actually a methane molecule is not flat like the structural formula. A model using balls for the atoms shows the real shape of the molecule. Figure 20-4 shows a model of a methane molecule.

Carbon atoms can share electrons with each other, too. Next to methane, the smallest hydrocarbon is ethane. Its formula is C_2H_6, and its structural formula is



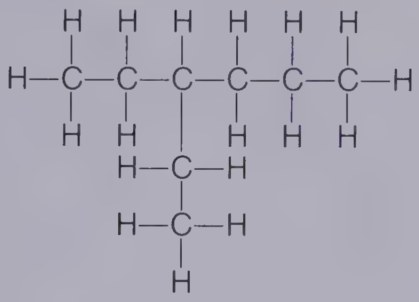
$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

Any number of carbon atoms can attach together in long chains. Gasoline is a mixture of several hydrocarbons. One of them is octane, C_8H_{18}:



$$\begin{array}{ccccccccccccccccccc} & & H & & H & & H & & H & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & C & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & | & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & H & & H & & H & & H & & \end{array}$$

The chains of carbon do not have to be straight. They can branch. Here is octane with a branched chain:



Is the branched octane C_8H_{18} too? Count the number of hydrogen and carbon atoms in the structural formula. Hydrocarbons with several carbon atoms can be branched in many different ways. There are 18 different kinds of octane. Now you have an idea of why there are so many carbon compounds.

Did You Get the Point?

The molecules of living things contain carbon.

Compounds containing carbon are called organic compounds.

Compounds of carbon and hydrogen are called hydrocarbons. Hydrocarbons are used as fuels.

Carbon atoms can form long chains, even branched chains. This is why there are so many different carbon compounds.

What Have You Learned?

1. You need energy to live. Explain why scientists say your energy comes from the sun.

2. Which of the following are organic compounds? (a) salt (b) sugar (c) water (d) DDT

3. Propane is a hydrocarbon, C_3H_8. Draw the structural formula for propane.

PETROLEUM GEOLOGIST

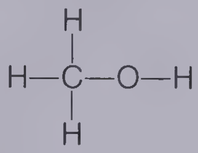
Without petroleum geologists there would be no oil industry. To find where to drill for oil, geologists study the earth in many different ways. They study the landscape from airplanes. They analyze rocks on the ground. They drill deep holes to study rocks underneath the earth's surface. Some geologists even search under the ocean. The man in the picture is throwing a shock-measuring device into the water. An underwater explosion will be set off. The device will measure the vibrations, telling the geologists what kinds of rock formations are on the ocean floor. Petroleum geologists also need to know about earthquakes, magnetic fields, and gravity. They use this information to detect pools of oil deep inside the earth.

People who explore for oil need a college degree in geology. Some petroleum geologists work in laboratories, studying rocks with complex instruments. Many others work "on site"—right at the well. They must have physical stamina and enjoy working outdoors. Their jobs may mean a lot of travel to out-of-the-way places.

Alcohols and Acids

20-4 Alcohols

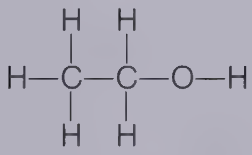
Carbon can combine with other elements besides hydrogen. Many important organic compounds contain oxygen. An alcohol has a formula like a hydrocarbon, but instead of one of the hydrogen atoms it has an OH group. Methyl alcohol, or methanol, has one carbon atom like methane:



$$\begin{array}{ccccccc} & & H & & & & \\ & & | & & & & \\ H & - & C & - & O & - & H \\ & & | & & & & \\ & & H & & & & \end{array}$$

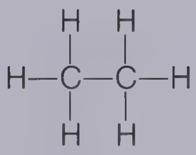
Methyl alcohol is also called wood alcohol. It is poisonous and can cause blindness. Methyl alcohol was used as antifreeze in car radiators. It is still used in windshield washing liquid.

Ethanol, or ethyl alcohol, has the same number of carbon atoms as ethane.



$$\begin{array}{ccccccccc} & & H & & H & & & & \\ & & | & & | & & & & \\ H & - & C & - & C & - & O & - & H \\ & & | & & | & & & & \\ & & H & & H & & & & \end{array}$$

ethanol



$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

ethane

Ethanol is also called grain alcohol. It is the alcohol in wine, beer, and liquors.

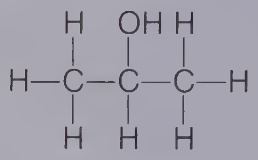
Materials
test tube, alcohol, red and blue litmus paper

★ Alcohols have an OH group. Does that mean they are bases? Test alcohol with red litmus paper and then with blue litmus paper. Mix some water with the alcohol. Test it again. What do you find? ★

In an alcohol, the O atom does not take electrons away from the C atom it is attached to. The O atom and the C atom share electrons. So the alcohol molecule does not break up into ions. This is why alcohols are not bases.

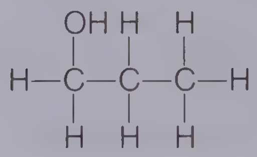
★ Draw the structural formula for propane, C_3H_8, with a pencil. Now erase one of the hydrogen atoms. Any one will do. In its place, put an OH group. You have drawn the structural formula for propyl alcohol. Compare your structural formula with those drawn by other students.

The propyl alcohol molecule is not flat. It can be turned and twisted. Look at the structural formulas with the OH group attached to the middle carbon atoms. If you turn some of the structural formulas upside down, they all look alike. They show the same molecule. This kind of propyl alcohol is called isopropyl alcohol.



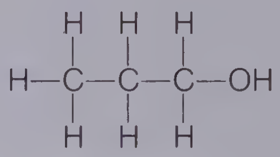
$$\begin{array}{ccccccccc} & & H & & OH & & H & & \\ & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & \\ & & H & & H & & H & & \end{array}$$

Compare the structural formulas that show the OH group attached to one of the end carbons. These are not the same as the structural formula for isopropyl alcohol. Your structural formula may be



$$\begin{array}{ccccccccc} & & OH & & H & & H & & \\ & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & \\ & & H & & H & & H & & \end{array}$$

or



$$\begin{array}{ccccccccc} & & H & & H & & H & & \\ & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & OH \\ & & | & & | & & | & & \\ & & H & & H & & H & & \end{array}$$

These structural formulas do not look alike. But if you made models, and turned and twisted them, you would find that the molecules are alike. Propyl alcohol with the OH group attached to one of the end carbons is just called propyl alcohol. Draw structural formulas for propyl alcohol and isopropyl alcohol. ★

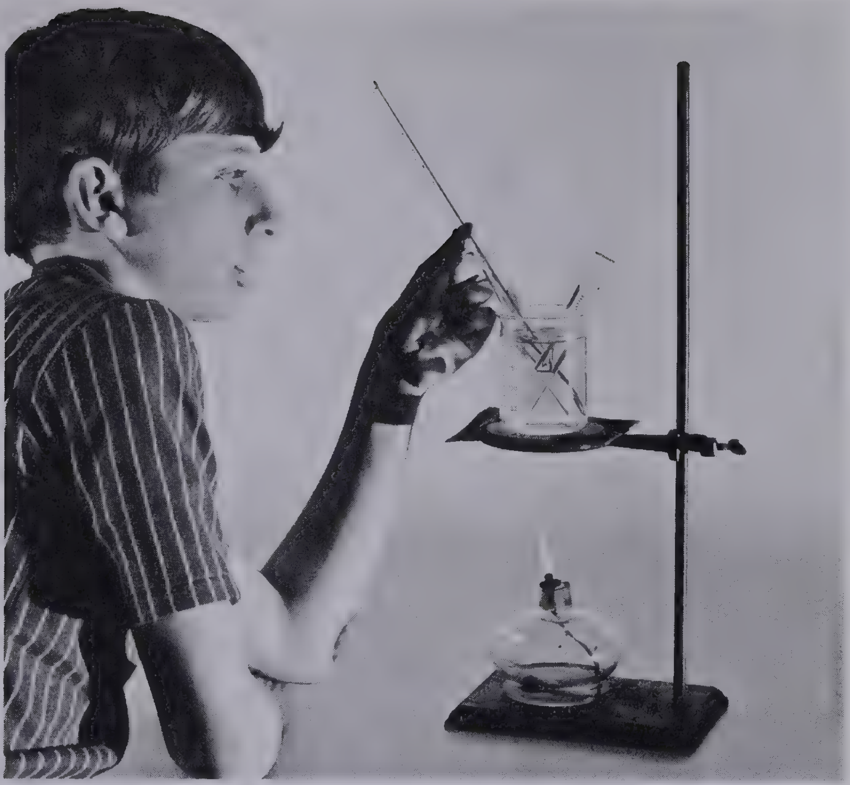
Propyl alcohol and isopropyl alcohol have different structural formulas. But they have the same formula, C_3H_7OH. They have the same molecular mass. Do they have the same properties? Or does the structural formula make a difference?

Materials
2 test tubes of alcohol, beaker, stand, burner, thermometer, test tube holder, test tube racks

★ Your teacher will give you two test tubes. Maybe one contains propyl alcohol and the other contains isopropyl alcohol. Or maybe they have the same liquid. Set the test tubes in a beaker half full of water. Light the burner. Put the beaker on a stand over the burner as in Figure 20-5. As you heat the beaker, stir the water gently. Watch the test tubes carefully.

When the alcohol in one or both of the test tubes boils, read the temperature and write it in your notebook. Then, using the test tube holder, take the boiling test tube out of the beaker. Set it in the rack to cool. When the alcohol

Figure 20-5 *Make sure the thermometer does not touch the bottom of the test tube.*



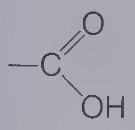
in both test tubes has boiled, put out the burner. Did both your samples of alcohol boil at the same temperature? Compare your results with those of other students. Do you think propyl alcohol and isopropyl alcohol have the same properties? ★

All the alcohols are alike in some ways. They will dissolve many organic compounds that will not dissolve in water. For example, when you take adhesive tape off your skin, some of the sticky stuff stays on your skin. The sticky stuff is made of organic compounds, something like rubber. It is very hard to wash off with water. But if you use rubbing alcohol (isopropyl alcohol), the sticky stuff dissolves in the alcohol and washes right off.

20-5 Organic acids

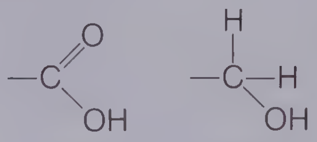
You can tell some of the properties of organic compounds by looking at their formulas. An organic compound whose formula contains only the letters H and C is a hydrocarbon. It will burn. An organic compound whose formula ends in the letters OH is an alcohol. It will dissolve many organic compounds.

Among organic compounds, an **acid** is a compound that contains the group



The two lines between the C and the top O mean that the carbon atom and that oxygen atom are sharing two pairs of electrons.

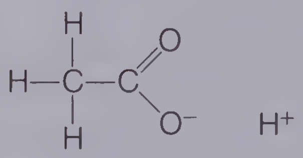
You can see that an organic acid has an OH group like an alcohol. But the acid has an oxygen atom where the alcohol has two hydrogen atoms.



acid alcohol

If you took these two hydrogen atoms away from an alcohol, and added an oxygen atom in their place, you would have an acid.

In water, a molecule of an organic acid can break up into ions. The hydrogen atom from the COOH group breaks away, leaving its electron behind, so it becomes an H^+ ion. Acetic acid breaks up like this:



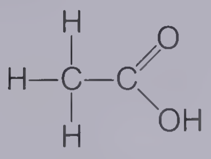
Actually, as you learned in Chapter 19, most of the acetic acid molecules do not break up into ions. Because most of the molecules of an organic acid do not break up into ions, organic acids are not very strong acids.

20-6 Alcohols and organic acids can react

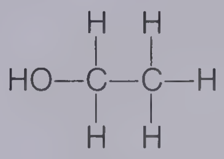
Materials
test tube, test tube holder, burner, acid, alcohol

★ Put some of the acid and some of the alcohol in your test tube. Your teacher will tell you how much to use. Your teacher will add a few drops of sulfuric acid. (The sulfuric acid is a catalyst.) Warm the test tube gently. Smell the test tube as in Figure 20-6. What does it smell like? ★

The acid reacts with the alcohol. Here are acetic acid and ethanol:



acetic acid



ethanol

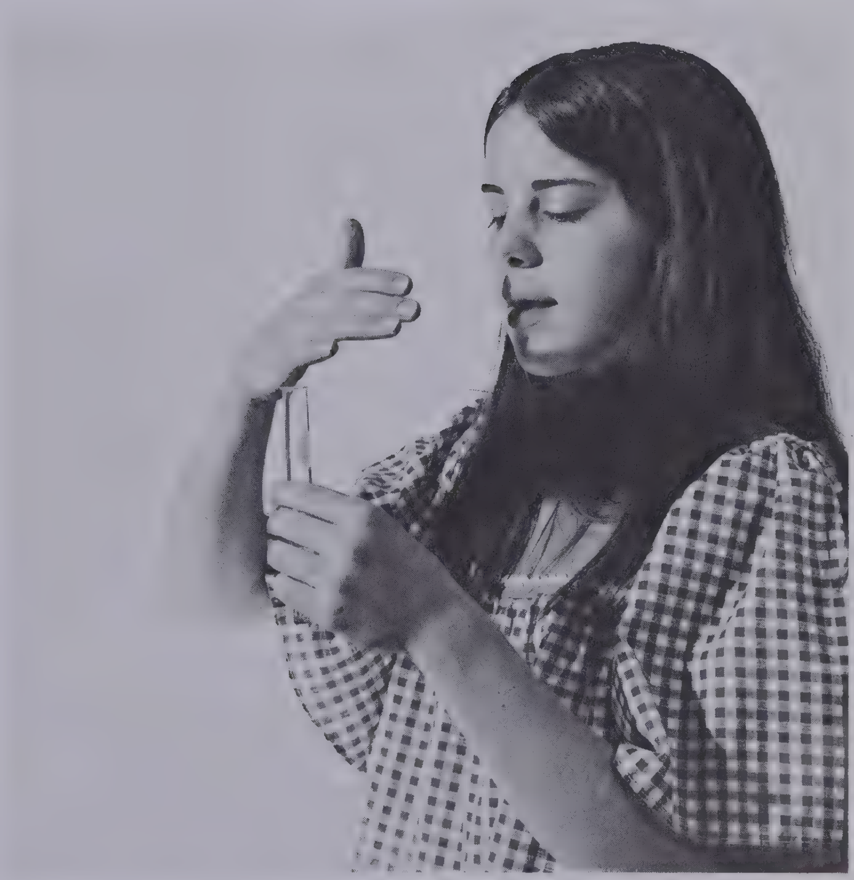
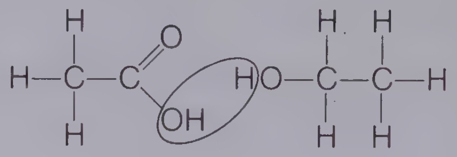
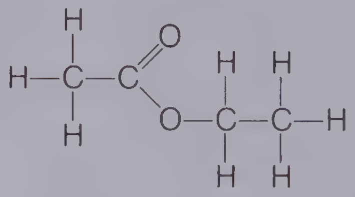


Figure 20-6 *To smell a chemical, hold the test tube about 6 inches from your nose. Use your other hand to fan the vapor toward your nose.*

When they react, an H and an OH break off and form a water molecule. This diagram shows what happens.



The other pieces of the acid and alcohol come together to form this molecule:



A compound like this is called an **ester.** Many esters smell good. Also, esters will dissolve many organic compounds. Esters are used in products like model glue and fingernail polish remover.

Remember that alcohols are not bases. If an acid and a base react, they form a salt and water. If an organic acid and an alcohol react, they form an ester and water. An ester is not a salt. An ester is made of molecules, not ions.

What would happen if an organic acid reacted with a base? It would form an organic salt. You can make an organic salt and see if it is something you know.

Materials
evaporating dish, spoon, salad oil, beaker, stand, burner, stirring rod, graduate, solution of sodium hydroxide in alcohol, 250-ml beaker, salt, thin cloth, jar, rubber band

★ Fats and oils contain organic acids called fatty acids. Put a tablespoon of salad oil in an evaporating dish. Get a beaker small enough so that the evaporating dish can sit on top of it. Fill the beaker almost half full of water. Put the beaker on a stand over a burner. Set the evaporating dish on top of the beaker (Figure 20-7). Stir the oil as it is heated.

Measure 10 ml of the solution of sodium hydroxide in alcohol. **Caution: Do not let it touch your skin.** Add it to the oil. Keep stirring the mixture until it becomes about as thick as mayonnaise. The alcohol does not take part in the reaction. It simply helps the sodium hydroxide to mix with the oil. What happens to the alcohol?

Fill a 250-ml beaker more than half full of water. Stir in two teaspoons of salt. Pour the thick stuff from the evaporating dish into the salt water. The salt makes thick curds form at the top of the water.

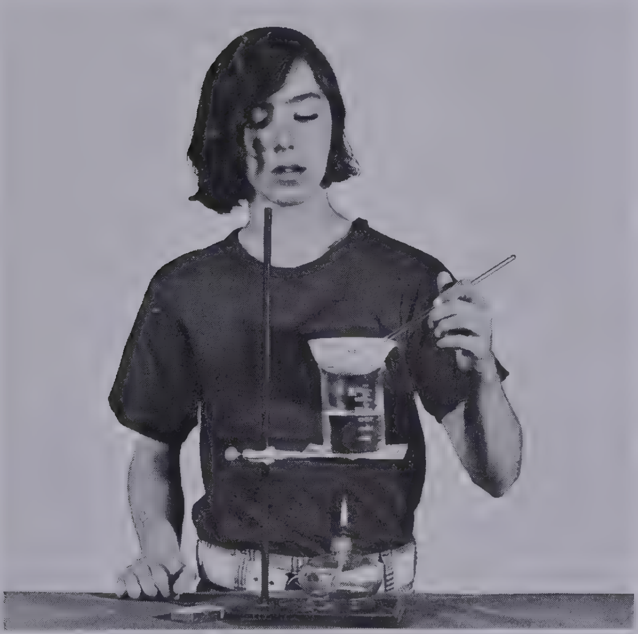
Hold a piece of thin cloth over the mouth of a jar. Fasten it with a rubber band. Carefully pour the water and curds from the beaker onto the cloth (Figure 20-8). Fill the beaker with water. Pour the water over the curds to remove the salt. Set the cloth aside to dry. What do you think the product is? ★

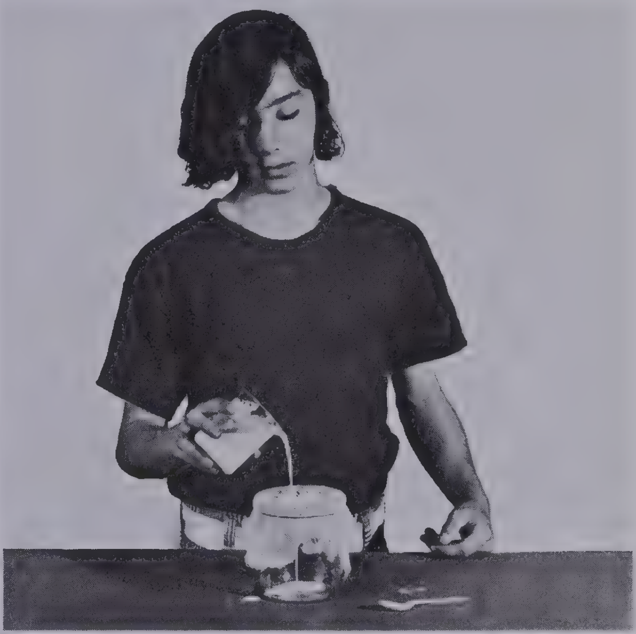
When an organic acid reacts with a base, an organic salt is formed. Some organic salts are called **soaps.** So you have made soap. The pioneers made soap in nearly the same way. They boiled fat with lye.

What does soap do? It takes dirt out of your clothes and skin. But how? Does soap dissolve dirt?

Figure 20-7 (*left*) *Stir the mixture carefully as it is heated in an evaporating dish.*

Figure 20-8 (*right*) *Strain the curds from the thick mixture.*





Materials
2 test tubes, masking tape, dirt, soap, 2 stoppers, spoon, oil

★ Label one test tube "soap." Put a little dirt into both test tubes. Fill each test tube half full of water. In the "soap" tube, put a little of the soap you made. The other tube is the control. Put stoppers in the test tubes. Shake both test tubes for one minute. Look at them. Did the soap dissolve the dirt?

Wash the test tubes. In one test tube, put half a spoonful of oil. Fill the test tube half full of water. Put the stopper on the test tube and shake it. Immediately look at the water and oil. What do they look like? Watch for several seconds. What happens?

Add a little of your soap to the water and oil. Stopper the test tube and shake it. If the soap does not foam up, add more soap and shake again. What do the water and soap and oil look like? What do they do? ★

Did You Get the Point?

You can tell some of the properties of a compound from the formula of the compound.

An alcohol has a formula like a hydrocarbon, but with one of the hydrocarbons replaced by an OH group.

An alcohol is not a base.

An organic acid contains a COOH group.

An organic acid and an alcohol react to form an ester.

An organic acid and a base react to form an organic salt, called a soap.

What Have You Learned?

1. Draw the structural formula for methyl alcohol. Draw the structural formula for the acid that could be made from methyl alcohol. This acid is found in ants.

2. What do you think soap does to water and oil? How does soap take dirt out of your clothes and skin?

Giant Molecules

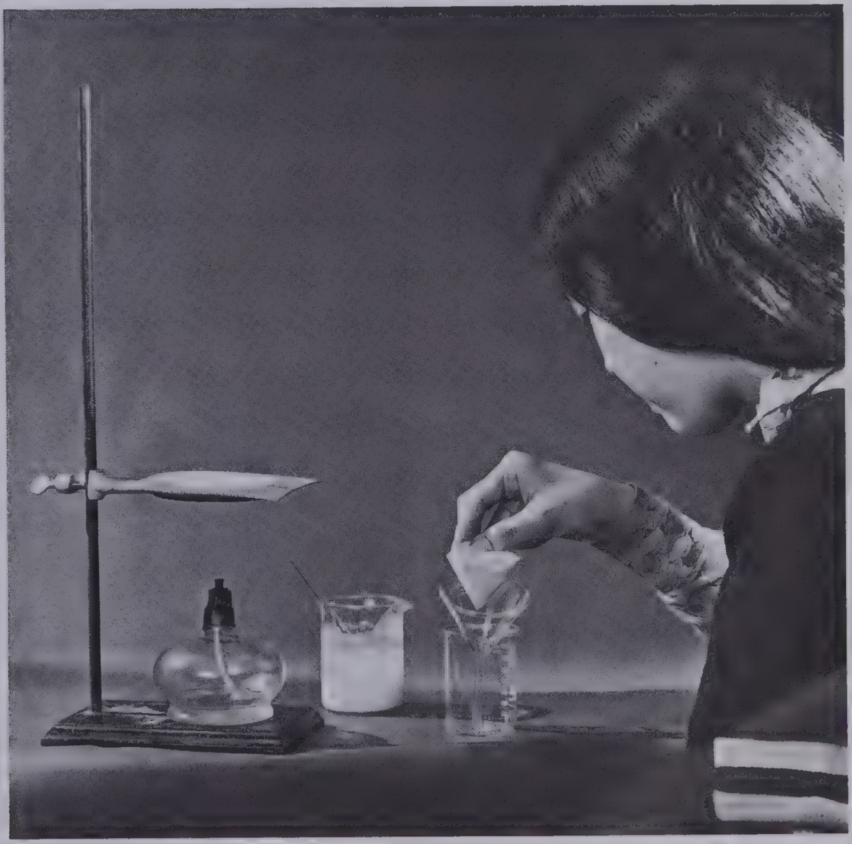
20-7 Many useful substances have giant molecules

Chemists are always looking for substances that will do a job better or faster or more cheaply. Sometimes the substance already exists in natural materials. The chemists try to find it and get it out.

Materials
graduate, skim milk, 250-ml beaker, tablespoon, vinegar, stand, burner, stirring rod, small beaker, funnel, filter paper, teaspoon, sodium bicarbonate

★ Put 100 ml of skim milk into a 250-ml beaker. Add one tablespoon of vinegar. Put the beaker on a stand over a burner. Heat it slowly, stirring all the time. In a few minutes, lumps (curds) will start to form in the milk. Take it away from the heat. Keep stirring until curds stop forming. Let the milk sit until the curds settle to the bottom (Figure 20-9). What you have done so far is a way to make cottage cheese.

Figure 20-9 *Let the curds settle while you get ready to filter the mixture.*



Pour as much liquid as you can off the curds into a small beaker. Set up a funnel with filter paper in it. Pour the curds into the funnel. Let them sit until nearly all of the liquid has drained away. Put the curds back in the 250-ml beaker. Add 40 ml of water and about $\frac{1}{4}$ teaspoon of sodium bicarbonate (baking soda). What do you think the sodium bicarbonate is for?

Now you have glue. Use it to glue two pieces of paper together. When it is dry, try to pull the pieces of paper apart. ★

Some white glues are made from milk. The glue is mostly an organic compound called casein (KAY-see-in). The casein was already in the milk. When you got rid of most of the other compounds in milk, the casein was left behind. Casein is used in paint as well as in glue. It helps the paint stick to the surface being painted. Casein is also used to make plastics.

Casein, plastics, and many other useful materials are alike in some ways. They are strong, bend easily, and are not very active. Many of the compounds with these properties have very large molecules. The giant molecules are made of many smaller molecules attached together. Substances like these are called **polymers.** The molecular mass of a polymer may be 400,000 or more. Casein is a natural polymer. So are cotton and wool (Figure 20-10).

Another important natural polymer is rubber. Latex is the sap of the rubber tree (Figure 20-11). Latex contains rubber molecules in a liquid. The rubber can be separated from the liquid by treating the latex with acid.

Materials
500-ml beaker or large jar, graduate, vinegar, latex, paper towels

★ Put about 50 ml of vinegar in the beaker. Fill the beaker about three-quarters full with water. Your teacher will give you some latex. The latex has ammonia in it to keep it from spoiling. **Caution: Try not to breathe the ammonia.** Roll up your sleeves. Pour the latex into the water. Put your hand in the water and try to work the rubber into a ball (Figure 20-12). This will take a minute or two.

When you have a good rubber ball, take it out and dry it. Make a pencil mark on paper and try to erase it with the rubber. How hard is the rubber? Pull on it. Does it go back to the shape it had before? See how high it bounces. ★

Figure 20-10 *Natural polymers.*

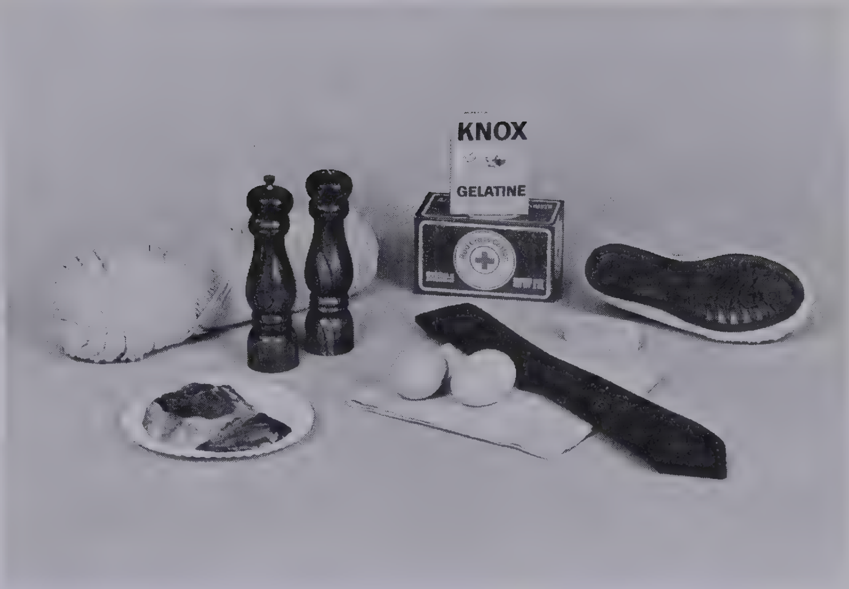
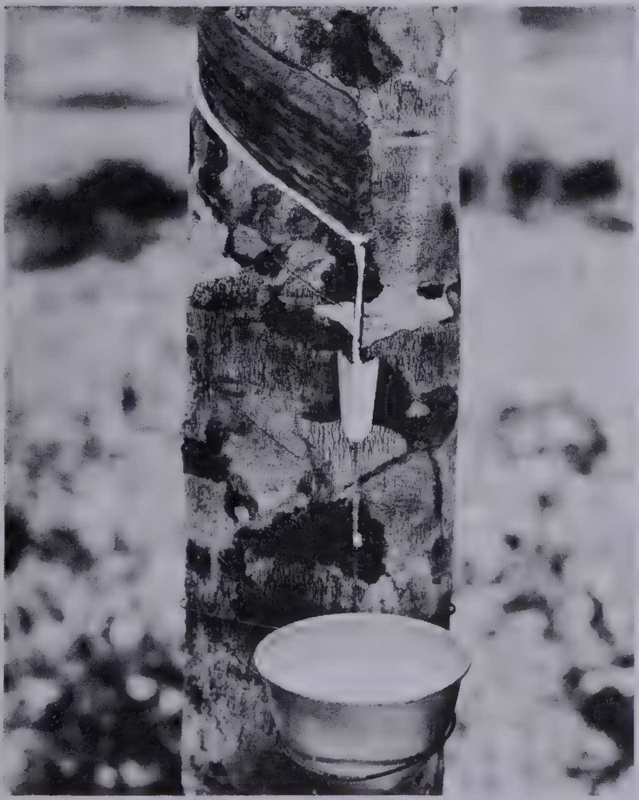


Figure 20-11 (*below*) *Latex dripping from the cut bark.*

Figure 20-12 (*lower right*) *Making a rubber ball from latex.*



Would the rubber you made be a good eraser? Could you make a good rubber band from it? A good basketball? A good tire?

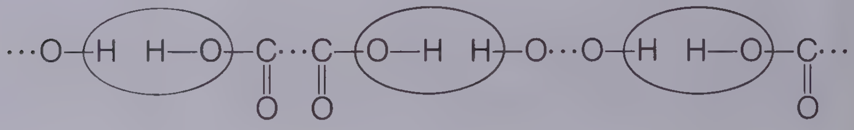
Chemists can improve natural materials. The rubber you make would not be useful for much. If it got cold, it would crack. If it got too warm, it would be sticky. More than 100 years ago, a scientist accidentally heated rubber and sulfur together. The new product was able to take high and low temperatures much better than plain rubber. Since then, rubber has been improved more and more. In 1925, a driver could expect a tire to last about 5000 miles. A tire made now will probably last at least 30,000 miles.

20-8 Man-made polymers

Often a substance is needed for a certain purpose, but nobody knows of a natural material with exactly the right properties. One of the first problems like this was to find a cheap substance to use instead of ivory for billiard balls. Other problems have been to find an unbreakable substance that you can see through, and a material for cloth that won't wrinkle.

When a chemist has a problem like these, he thinks about the substances he knows. Some of them have properties like the properties of the substance he needs. What groups of atoms will give it the right properties? What molecular mass should it have? The chemist has an idea of the material in his mind and then tries to build the actual substance in the laboratory.

Suppose a substance is needed that has some properties like an ester, but also has a high molecular mass. A polymer can be made with these properties. Remember that an alcohol (OH group) and an organic acid (COOH group) react to form an ester. There are compounds whose molecules have an OH group at each end. And there are compounds whose molecules have a COOH group at each end. If we write ··· for the middle of each molecule, we can draw a diagram of the substance like this:



$$\cdots \mathrm{O}\!-\!\mathrm{H}\quad \mathrm{H}\!-\!\mathrm{O}\!-\!\underset{\substack{\|\\ \mathrm{O}}}{\mathrm{C}}\cdots\underset{\substack{\|\\ \mathrm{O}}}{\mathrm{C}}\!-\!\mathrm{O}\!-\!\mathrm{H}\quad \mathrm{H}\!-\!\mathrm{O}\cdots\mathrm{O}\!-\!\mathrm{H}\quad \mathrm{H}\!-\!\mathrm{O}\!-\!\underset{\substack{\|\\ \mathrm{O}}}{\mathrm{C}}\cdots$$

When the atoms in the circles break off and form water molecules, the other parts of the acid and alcohol molecules join into a new long molecule. The new compound is called a polyester. One kind of polyester is called "Dacron." Polyesters are made into thread for clothing that does not wrinkle easily. Other man-made polymers include "Nylon," "Lucite," "Plexiglas," and "Saran."

Man-made polymers.

Did You Get the Point?

Substances whose molecules are made of many smaller molecules attached together are called polymers.

Some polymers are found in natural materials. Other polymers are man-made.

What Have You Learned?

1. List some polymers that you often use or see. For each one, tell whether it is natural or man-made, what it is used for, and what properties it has that make it useful for this purpose.

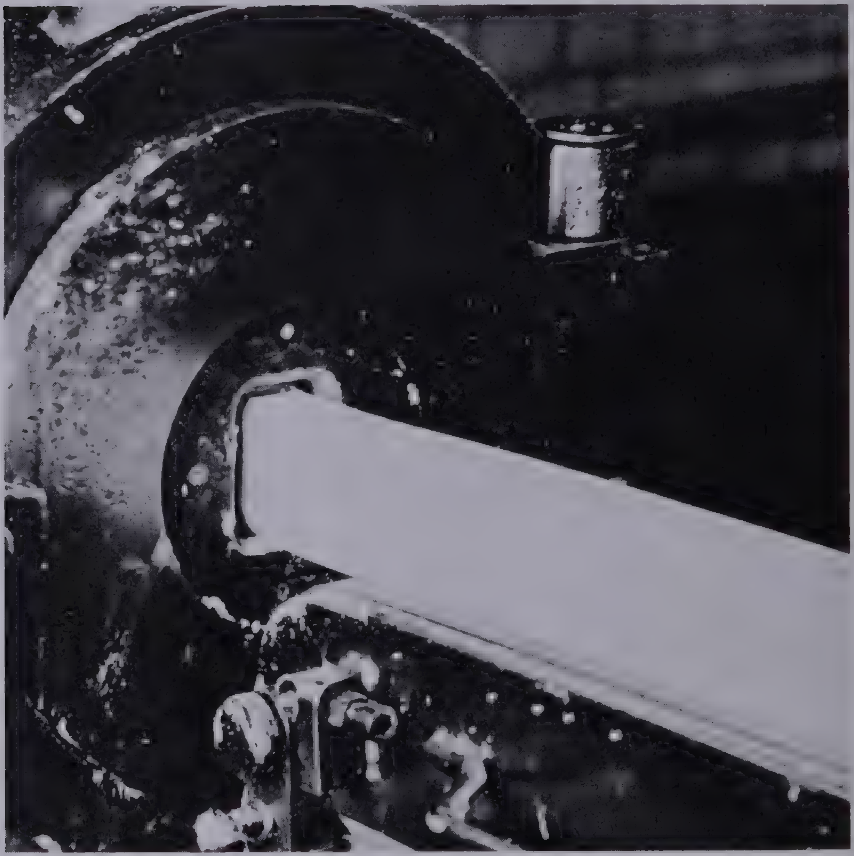
SKULLDUGGERY

1. Some foods are labeled "organic" or "organically grown." What does the word *organic* mean when it is used this way? Does it have the same meaning when a chemist uses it? Do you think natural materials are better than man-made materials? Do you think man-made materials have made our lives better? Explain.

2. One brand of soap claims it dissolves more slowly. Plan an experiment to test this claim. Is slow dissolving an advantage or a disadvantage?

One brand claims to be 99 44/100% pure. What does this mean? How could you find out if it is true?

Look at the labels of several bars of soap. Do they list any additives? What are the additives for? Compare the prices of different brands. Are you paying for soap, perfume, deodorant, or advertising?



This long bar of soap is ready to be cut into smaller bars and wrapped.

FOR FURTHER READING

Asimov, Isaac. *The World of Carbon,* rev. ed. New York: Abelard-Schuman Ltd., 1966. A simplified discussion of carbon and many of its compounds.

Baxter, Eric. *Study Book of Oil.* Chester Springs, Pa.: Dufour Editions, Inc., 1960. Discovery, processing, and uses of oil.

Stone, A. Harris, and Bertram M. Siegel. *The Chemistry of Soap.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1968. Surface tension, solubility, density, evaporation, cohesion. Experimental approach with pictures.

Wohlrabe, Raymond A. *Exploring Giant Molecules.* New York: World Publishing Company, 1969. Determination of the composition, structure, and synthesis of sugars, starches, and proteins.

WHAT'S NEXT?

All living things are made of organic compounds. In the next chapter you will learn more about the compounds your body is made of—the ones you eat.

HOT
3 99
49
49
OPTIMO
3 LBS 35
89

Chapter 21

The Chemistry of Food

Have you ever sat in a classroom waiting eagerly for lunch? You stared at the clock but the hands hardly seemed to move. Maybe you were really hungry or maybe you simply didn't want to be in class. Sometimes people eat because they are bored. Sometimes they eat because they like the taste of the food. But most of the time people eat because they are hungry. Their bodies are sending messages that they need food.

Your body needs food for fuel. The food supplies the energy you need to run, to breathe, or even to think. While you are growing, food supplies the materials from which bone and teeth and muscle are made. Food also supplies materials to replace parts of the body that are naturally used up. You don't keep the same skin or blood or hair your whole life.

There are about 50 different substances that humans need to stay alive. Some of these substances are very common like water and oxygen. But you may not have heard of others like selenium and vitamin K. No single food can supply everything you need.

The Chemicals That Keep You Alive

21-1 Carbohydrates

Much of your energy comes from a group of organic compounds called carbohydrates. **Carbohydrates** (kar-boh-HY-drayts) are made from the elements carbon, hydrogen, and oxygen. Most simple carbohydrates have the formula $C_6H_{12}O_6$. They each have a slightly different structural formula. They are called simple sugars. You can test for simple sugars with a mixture called Benedict's solution.

Materials
glucose, fructose, sucrose, water, Benedict's solution, 3 test tubes, beaker, stand, wire gauze, burner, clamps, graduate, marking pen

★ Put 10 ml of glucose solution in a test tube. Rinse your graduate and then measure 10 ml of fructose solution for the second test tube. Rinse again. Then put an equal amount of sucrose solution in the third test tube. Label the test tubes. Add 10 ml of Benedict's solution to each test tube.

Set up a water bath as shown in Figure 21-1. Let your test tubes sit in the boiling water for about ten minutes.

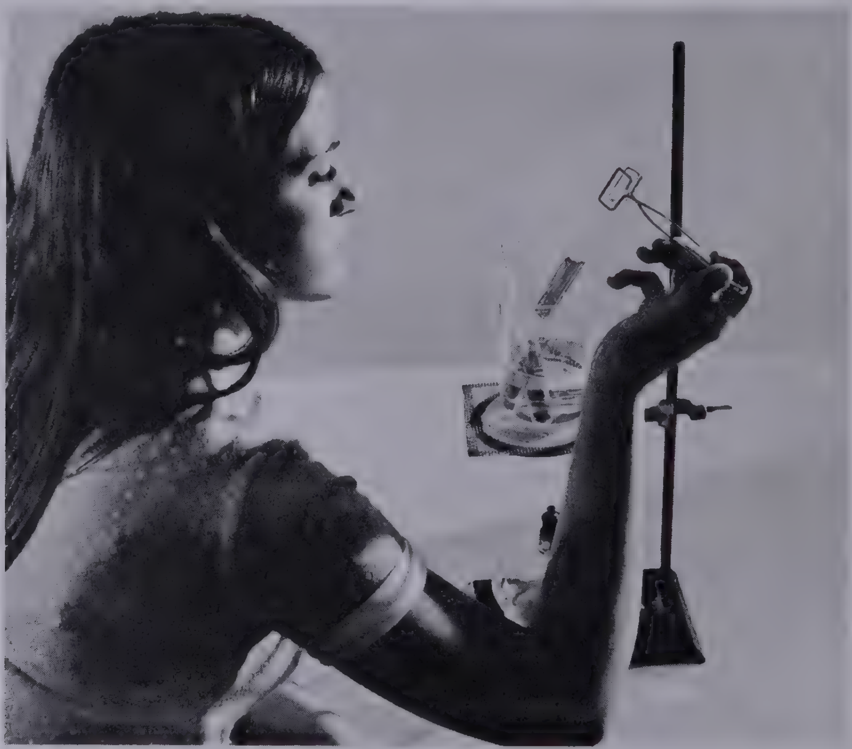


Figure 21-1 *Be sure your water bath cannot tip over. Boiling water is dangerous.*

How do you know a reaction is taking place? Which of the sugars are simple sugars? ★

Glucose and fructose both have the formula $C_6H_{12}O_6$. But they differ in the way the atoms are arranged in the molecule. Sucrose is not a simple sugar. It has the formula $C_{12}H_{22}O_{11}$. A molecule of glucose and a molecule of fructose join to make a molecule of sucrose. The second product of this reaction is a molecule of water. Sucrose is also called table sugar. It is the sugar that people sprinkle on cereal or put in tea. Concentrated hydrochloric acid can split sucrose into the two simple sugars, fructose and glucose.

Materials
foods, test tubes, water bath, Benedict's solution, burner

★ Test each of the foods that you are given in this way: Add a small amount of food to 5 ml of water in a test tube. Add 5 ml of Benedict's solution. Heat the test tube in a water bath. Keep a record of the results. ★

21-2 Starches

Not all carbohydrates are as simple as glucose or even sucrose. When many glucose molecules join together in a long chain, a polymer called **starch** is formed. The test for starch is very simple.

Materials
3 test tubes, water, ice, potato starch, corn starch, iodine solution, burner, beaker, wire gauze, ringstand, ring

★ Heat some water in a beaker until it is lukewarm. Put 10 ml of warm water in each test tube. Add a small amount of potato starch to the first test tube and a small amount of cornstarch to the second. Don't add anything besides water to the third test tube. Label the test tubes.

Put the three tests tubes in a beaker of ice water for a few minutes. Then add a few drops of iodine solution to each test tube. What happens? Why did you use the third test tube if you were only testing two materials? ★

Materials
foods, test tubes, iodine solution, graduate

★ A number of common foods contain starch. Mix each food with 5 ml of water in a test tube. Add a few drops of iodine solution. Write the results of the tests in your notebook. ★

Probably you have never eaten a raw potato. There is a good reason why people cook potatoes. From your tests, you know that raw potato contains starch but cooked potato contains simple sugar. Your body must change starch to sugar before it can use it for energy. Foods are also cooked to soften them.

Materials
cracker, 4 test tubes, iodine, Benedict's solution, water bath, burner

★ Label your test tubes 1, 2, 3, and 4. Break your cracker in half. Then break one piece in half again. Put one small piece in test tube 1 and another in test tube 2. Your teacher will tell you what number to count to while you chew half the cracker. Do not swallow the cracker. Put half of the chewed cracker in test tube 3 and half in test tube 4.

Test tubes 1 and 3 with Benedict's solution. Test tubes 2 and 4 with iodine solution. Is there a difference between the chewed and unchewed crackers? Did the length of time that you chewed the cracker change the results? ★

Saliva contains a substance that breaks the large molecules of starch into small molecules of simple sugar. Saliva helps to digest food and to make the food easier to swallow.

21-3 Fats

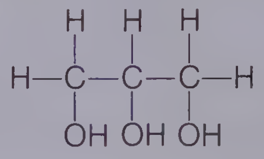
When many people think of fats, they think of calories or of extra body weight. But you must eat some fats to stay healthy. For example, some babies develop skin rashes. Scientists have shown that too little fat in a baby's diet can cause these rashes. Fats are also an important source of energy. One gram of fat gives more than twice the energy of one gram of carbohydrate.

Materials
foods, brown wrapping paper

★ In some foods, like butter or salad oil, the fats are easy to see. (Oils are fats that are liquids at room temperature.) But many foods contain fats that you can't see. Rub a small amount of the food you wish to test on the wrapping paper (Figure 21-2). Put a small drop of water on the paper as a control. Put the name of each food under each spot. Let the paper sit for a few minutes so any water in the foods can evaporate.

After all the spots are dry, hold the paper up to the light. The foods that contain a lot of fat will make a spot that light can shine through. Write down the results in your notebook. ★

Most fats are esters. Remember that an ester is a product of the reaction of an acid and an alcohol. The alcohol from which fats are made is called **glycerol** (GLIS-uh-rol). The structural formula for glycerol is:



$$\begin{array}{ccccccc} & & \text{H} & & \text{H} & & \text{H} & & \\ & & | & & | & & | & & \\ \text{H} & — & \text{C} & — & \text{C} & — & \text{C} & — & \text{H} \\ & & | & & | & & | & & \\ & & \text{OH} & & \text{OH} & & \text{OH} & & \end{array}$$

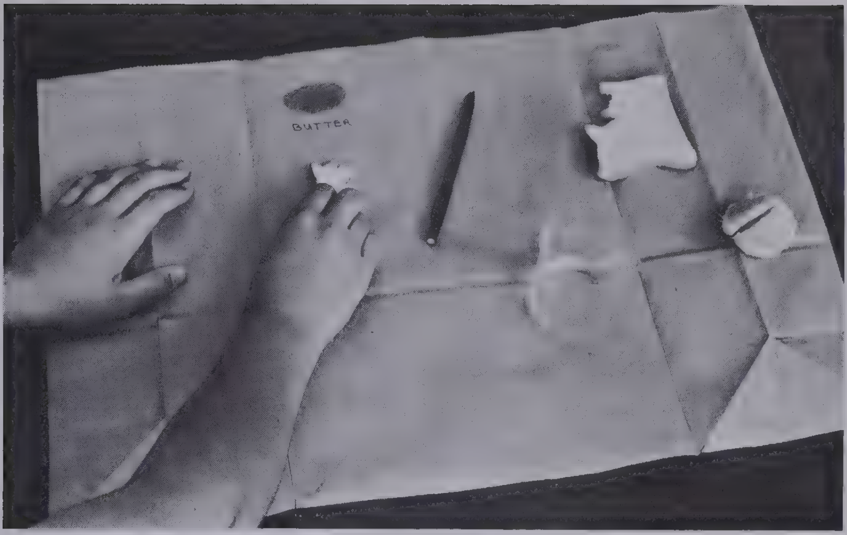


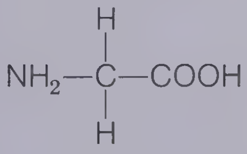
Figure 21-2 *Label each spot right away so you will not get them mixed up.*

Three molecules of acid can react with one molecule of glycerol. The acids that produce fats are called fatty acids. There are many different fatty acids. Butter contains at least 29 different ones. One example of a common fatty acid is oleic acid. Its formula is $C_{17}H_{33}COOH$. You don't have to remember this formula. It just gives you some idea of the size of a fat molecule. Remember that three of these large molecules join with glycerol to make a fat molecule.

21-4 Proteins

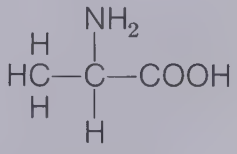
The average human body is 50 to 60 percent water. The next largest ingredient is protein. Protein can supply energy but more important, proteins are the "building blocks" of the body. Some people need more protein than others. A growing child and a pregnant woman need extra protein.

Proteins are long chains of smaller molecules called amino acids. This means they are polymers of amino acids. **Amino acids** contain both the COOH group and an NH_2 group (the amino group). Here are the structural formulas for two fairly simple amino acids:



$$\begin{array}{ccccc} & & \mathrm{H} & & \\ & & | & & \\ \mathrm{NH_2} & - & \mathrm{C} & - & \mathrm{COOH} \\ & & | & & \\ & & \mathrm{H} & & \end{array}$$

glycine



$$\begin{array}{ccccc} & & \mathrm{NH_2} & & \\ \mathrm{H} & & | & & \\ \mathrm{HC} & - & \mathrm{C} & - & \mathrm{COOH} \\ \mathrm{H} & & | & & \\ & & \mathrm{H} & & \end{array}$$

alanine

There are about 20 amino acids that your body needs to keep healthy. Some proteins have as few as 50 amino acids in their chain. Some have as many as 3000. The order in which the amino acids join also varies. Think about the letters in the alphabet. There are only 26 of them. But with these 26 letters, you can make all the words in the dictionary. With 20 amino acids, your body can make thousands of proteins.

Materials
foods, ninhydrin solution, test tubes, clamps, water bath, burner

★ There are a number of tests for protein. The one that you will do is called the ninhydrin test. Make a table like this one in your notebook.

food	amount of protein		
	much	little	none
?	?	?	?

Put enough ninhydrin solution in a test tube to just fill the curved bottom. Add a small piece of the food to be tested. Then heat the test tube for about four minutes in a boiling water bath.

If the solution turns purple, the food being tested contains a lot of protein. If the solution turns blue-green, light green, or red, the food contains little protein. If the solution does not change color, there is no protein. Heat tap water and ninhydrin solution in one test tube as a control. Write the results in your notebook. ★

21-5 Vitamins

Eating the proper amounts of carbohydrates, fats, and proteins is not enough to keep you healthy. Your body needs oxygen, water, and salts. It also needs small amounts of other organic substances called **vitamins.** *Vita* is the Latin word for life. Vitamins are necessary for life.

Vitamins help proteins with an important task. Some proteins act as catalysts for the chemical reactions in the body. These proteins are called enzymes. **Enzymes** are organic catalysts. Some enzymes cannot work without a partner. Vitamins act as the partners for enzymes. Without vitamins your body cannot use food.

Figure 21-3 *Table of vitamins.*

vitamin	best sources
A	Fish-liver oils, green plants, carrots
D	Fish oils
E	Grain and vegetable oils
K	Green vegetables
B_1	Pork, liver, whole grains
B_2	Milk, egg white, liver, leafy vegetables
Niacin	Yeast, wheat germ, meats
B_3	Liver, kidneys, green vegetables, egg yolk
B_6	Whole grains, yeast, egg yolk, liver
Inositol	Whole grains, liver
H	Liver, kidney, yeast
Choline	Egg yolk, brain, grains
p-Aminobenzoic acid	Yeast
M	Liver, deep green leafy vegetables
B_{12}	Liver, meats
C	?

Figure 21-3 lists the vitamins and some foods in which they are found. Notice that the foods that contain Vitamin C are not given. There isn't one general test for all the vitamins. But there is a fairly simple test for Vitamin C. You will find out for yourself what foods are the best sources of Vitamin C.

Materials
foods, indophenol solution, Vitamin C solution, test tubes, water, dropper, stirring rod

★ Vitamin C dissolves in water. Test the dilute solution of Vitamin C and water in this way. Put 5 ml of indophenol in a test tube. Add the Vitamin C solution drop by drop. Swirl the test tube gently between drops. Find out how many drops it takes before the indophenol becomes colorless.

The reaction of Vitamin C and indophenol will act as a control. If you had used a concentrated solution, one drop would have changed the color. Test foods that are liquids by adding them drop by drop to 5 ml of indophenol in a clean test tube. Wash out the dropper before testing a new food. Test foods that are solid by mashing them with a stirring rod in a small amount of water. Then you can add drops of the water solution to the indophenol. Write the results of each test in a table in your notebook. ★

What kinds of foods should you eat to get enough Vitamin C? When people lack Vitamin C, the skin cracks at the corners of their mouths. The gums bleed and their teeth may become loose. This condition is called **scurvy.** About 0.030 g of Vitamin C a day can prevent scurvy. But doctors and diet specialists usually recommend at least 0.075 g daily. (You get more than 0.1 g in a cup of orange juice.) They think that Vitamin C helps heal cuts and burns. It is also possible that this vitamin can prevent infections.

Some scientists think that large doses of Vitamin C can stop people from getting colds. They say that you should have at least 1 g of Vitamin C daily. No one has been able to show that Vitamin C does prevent colds. But there is no evidence that large doses of the vitamin are harmful. Your body doesn't store extra Vitamin C. You get rid of extra Vitamin C with other body wastes. But large doses of some vitamins are harmful, so you shouldn't take lots of multi-vitamin pills.

21-6 Minerals

The final group of chemicals that are necessary for life are not large organic molecules. **Minerals** are ions of metallic and non-metallic elements. The following table lists those elements that your body uses. The elements that have stars next to them are needed in very small amounts.

minerals

calcium
chlorine
* chromium
* cobalt
* copper
* fluorine
* iodine
iron
magnesium
* manganese
* molybdenum
phosphorus
potassium
* selenium
sodium
sulfur
* zinc

Materials
food, balance, crucible, burner, ringstand, ring, triangle, test tube, water, stopper, dropper, silver nitrate, sodium oxalate, potassium thiocyanate, funnel, filter paper

★ You can test for some of the minerals in foods. Find the mass of the empty crucible. Find the mass of the crucible with the food in it. Subtract to find the mass of the food. Heat the food in the crucible until only white or gray ashes are left. Let the crucible cool. Then find the mass of the crucible and the ashes. Subtract to find the mass of the ashes. Compare the amount of ashes to the original mass of food.

Dissolve the ashes in 10 ml of water. Wet your filter paper with water before you filter the solution. The solution won't be wasted by being soaked up by the filter paper. Divide the filtered liquid into three parts in three clean test tubes. Add a few drops of silver nitrate solution to the first test tube. A white precipitate shows that there were chloride (Cl^-) ions in the food.

Add a few drops of sodium oxalate solution to the second test tube. If there is a lot of calcium in your food, you will get a white precipitate. If there is a lot of iron in your food, you may get some pale yellow precipitate with sodium oxalate. For a better test for iron, add potassium thiocyanate solution to the third test tube. Iron will turn the solution red.

Record your results and those of your classmates in a table like this one.

food	**calcium**	**iron**	**chlorine**
?	?	?	?

What foods are high in calcium? in iron? in chlorine? ★

Your body needs calcium for making bones and teeth. Calcium also helps to control the clotting of blood and the beating of your heart, and helps carry messages in the nervous system.

Most of the body's supply of iron is found in the blood. Iron helps to carry oxygen to all parts of the body. A lack of iron can cause a condition called anemia (uh-NEE-mee-uh). Someone with anemia may feel weak and tired, and have a poor appetite.

Chlorine works with sodium and potassium in the body. You get most of your chlorine combined with sodium in table salt. These three elements help to control the amount of water in cells, and the amount of acids and bases in the blood. Chlorine is part of the stomach acid that helps to digest food.

Did You Get the Point?

Five groups of chemicals are needed by the human body: carbohydrates, fats, proteins, vitamins, and minerals. Carbohydrates are compounds of carbon, hydrogen, and oxygen.

Simple sugars can be tested with Benedict's solution. Starches can be tested with iodine.

A substance in saliva helps break down starch into simple sugars.

Most fats are esters of glycerol and fatty acids. Fats and carbohydrates supply most of the energy for the body.

Proteins are long chains of amino acids. Proteins are the building materials of the body. They also supply some energy and act as catalysts for reactions.

Enzymes cannot control reactions without the help of vitamins and minerals.

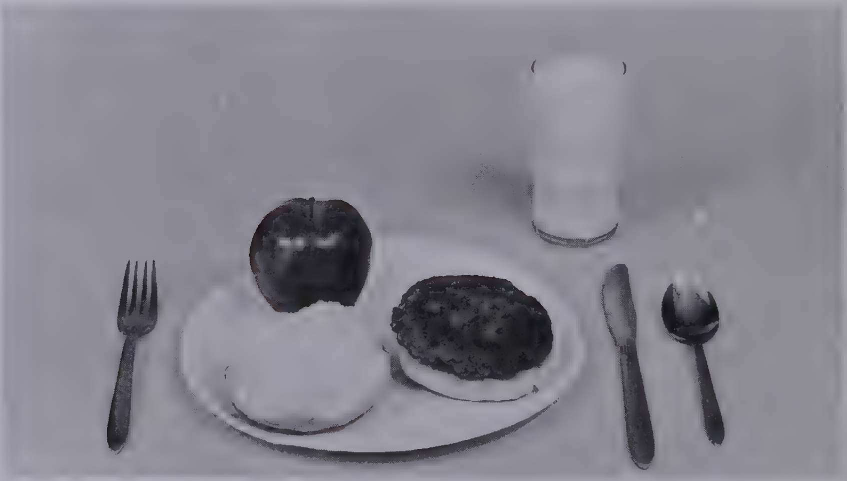
What Have You Learned?

1. Which foods, in general, are highest in protein, in carbohydrate, in fat, and in Vitamin C?

2. Which are lowest in protein, in carbohydrate, in fat, and in Vitamin C?

3. Can everybody afford the best kinds of food?

Tell whether each food contains carbohydrates, fats, proteins, and Vitamin C.



DIETITIAN

Everyone needs food. But some people need special diets, in order to stay healthy or to get well. What a diabetic eats, for example, may be a life or death matter. Pregnant women, nursing mothers, and athletes in training may need to change their eating habits. After a serious illness, a carefully planned diet can help a patient recover faster.

In cases like these, a doctor may recommend that a dietitian plan diets for a person's special needs. Then the dietitian talks about the new diet with the person, and makes sure that he will be able to follow the diet at home.

Some dietitians work in places like hospitals and school cafeterias. They do not work so closely with individuals. Instead, they are responsible for planning healthful menus for groups of people.

People who plan to become dietitians study nutrition in college. Then they gain experience by working with expert dietitians.

The Ways Foods are Changed

21-7 Food can spoil

The food you eat may have been shipped long distances. It may have been stored for a long time. Some foods can be stored for months without spoiling. Sugar is one example. What are some others?

Most foods will spoil if you just leave them sitting on a kitchen shelf. Bacteria, molds, and yeasts cause foods to spoil. These tiny living things (too small to be seen without a microscope) make compounds that can change the flavor, color, or smell of food. Some of these compounds make food more attractive. The ''blue'' in blue cheese is mold. (But people who splurge on blue cheese would not eat moldy bread!) Sometimes these compounds can make people sick. Bacteria in foods can sometimes cause food poisoning.

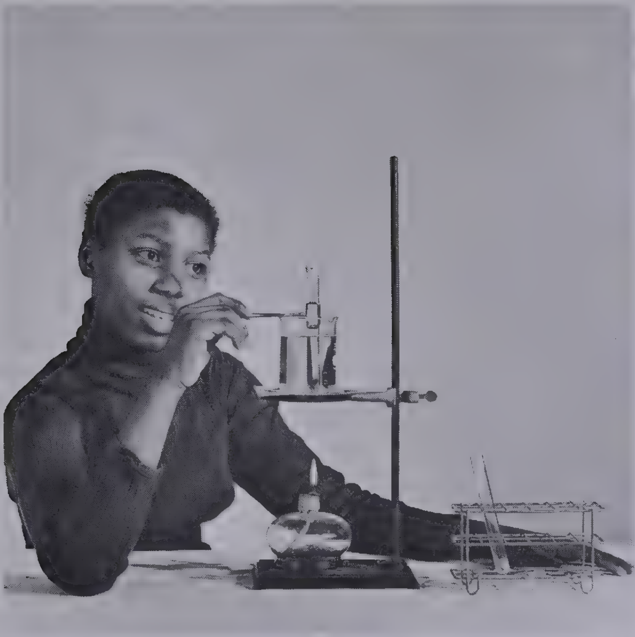
Bacteria, yeasts, and molds need water to live. One way to prevent spoiling is to take the water out of food. Removing the water is called **dehydration.** Powdered, or dehydrated, milk can be stored for months on a shelf. How long would milk stay fresh outside a refrigerator? How long does it stay fresh in a refrigerator?

21-8 Using heat and cold to prevent spoiling

You know that food keeps longer in a refrigerator than in a warm kitchen. If it is frozen, it can keep for months. Remember that changing the temperature changes the speed of a reaction. Low temperatures slow down chemical reactions. A freezer can slow reactions down more than a refrigerator can. Heat speeds up reactions. But enough heat can also keep food from spoiling.

Materials
hamburger, 2 test tubes, cotton plugs, test tube holder and rack, beaker, burner, marking pen, microscope, slide, coverslip, dropper

★ Divide your piece of hamburger in half. Put one half in each test tube. Make sure the pieces are touching the bottom of the tube. Half fill each tube with water. Plug the tubes with cotton and mark them so that you can tell them apart.



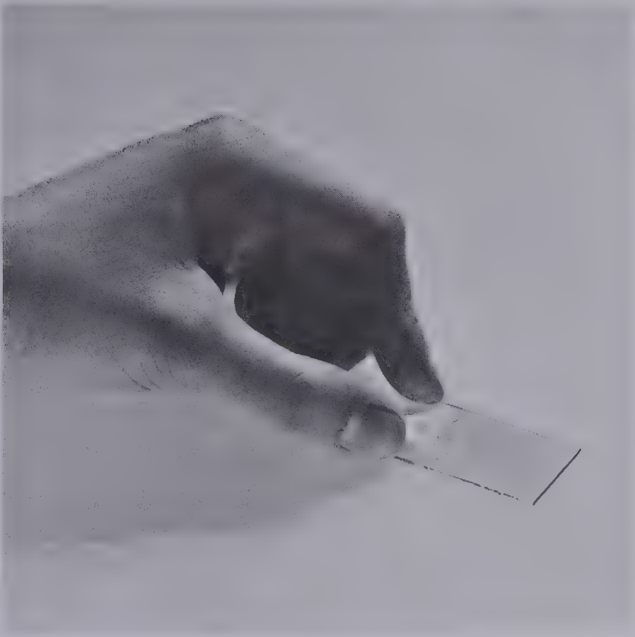


Figure 21-4 (*left*) *Which test tube is the control?*

Figure 21-5 (*right*) *Try not to pick up any solid material.*

Place one tube in boiling water as shown in Figure 21-4. Leave it in the boiling water for 15 minutes. Use a test tube holder to remove the hot tube from the water bath. Place both tubes in the same test tube rack and leave the rack in a warm place. Check the tubes every day for three days. Do not remove the plugs until the third day. Look for any changes in color, texture, or smell.

Put a glass slide on your table or desk. Place a drop of water from the unheated test tube on the slide. Holding only the edges carefully pick up a coverslip. Put one edge of it beside the drop of water on the slide as shown in Figure 21-5. Slowly lower the coverslip. The water should spread under it. Do not trap any bubbles. If you lower the coverslip too quickly you will probably get some bubbles.

Look at your slide under the microscope. If you do not know how to use the microscope, your teacher will help you. Make a second slide with a drop of water from the test tube that was heated. What did you see when you looked at the drops of water? Did both the drops look the same? ★

When you boiled the hamburger, the heat killed the tiny living things in it. They no longer could react to spoil the food.

21-9 Other ways to prevent spoiling

Before refrigerators were invented, people had trouble keeping their foods from spoiling. Some of them learned to salt their foods. Others tried pickling or smoking food. The bad taste of food that was beginning to spoil could be disguised with spices. We still use spices in cooking. But now we use them mostly because we like their flavor, not to disguise spoiled food. One spice, cloves, contains a chemical that prevents the growth of bacteria. Cloves are still used to preserve Virginia ham.

Materials
2 slices of bread

★ Many manufacturers add chemicals to their foods to keep them from spoiling. A chemical called sodium propionate is added to bread to slow down the growth of mold. Take a slice of bread that contains sodium propionate and a slice of bread without it. Put both slices of bread in a warm (not hot) place. Check the bread every day until some mold forms. Does mold form on both slices? Does it take longer to grow on one of the slices? ★

Chemicals are not always added to food just to prevent spoiling. Carbon dioxide is added to drinks to make them fizz. Calcium phosphate is added to salt to keep it from lumping. Most flour is bleached because people prefer it white, while some fruits are artificially colored because people like brightly colored fruit. Chemicals are used to tenderize meat, to neutralize acids, to sweeten some foods and to thicken others.

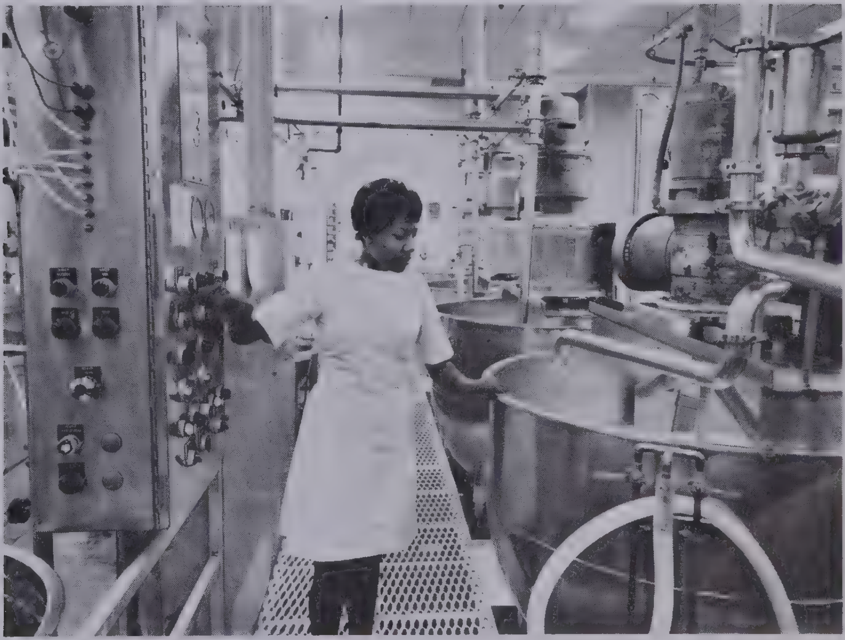
21-10 What happens to the vitamins?

Heat makes food easier to digest. Heat also helps to preserve food. But how do heat (and cold) affect vitamins?

Materials
canned, frozen, and fresh juice, indophenol, dropper, test tubes, rack, graduate

★ Label the test tubes A, B, and C. Put 5 ml of indophenol in each test tube. Add the canned juice to the first test tube drop by drop. Write down how many drops it takes till the Vitamin C in the canned juice changes the color of

The top photo shows one way that food was preserved in 1917. This cannery was started by some New England women. The girl on the left is sterilizing the jars for the apple jelly over a kerosene stove. In the bottom photo, the woman is setting computer controls to mix a 300-gallon batch of cream sauce.



the indophenol. Use frozen juice in test tube B and fresh juice in test tube C. ★

Did all the juices have the same amount of Vitamin C? Did freezing the juice destroy any of the Vitamin C? When juice is canned, it is heated to kill the bacteria. Did the canned juice have less Vitamin C than the fresh juice?

Materials
juice, indophenol, dropper, test tubes, rack, graduate

★ There is another way to test whether heat affects Vitamin C. Test some juice that has been boiled and then cooled. Also test some juice that was left uncovered overnight. Use 5 ml of indophenol for each test. Did boiling affect the amount of Vitamin C? Did leaving the juice uncovered affect the amount of Vitamin C? ★

Did You Get the Point?

Bacteria, yeasts, and molds cause food to spoil.

Dehydration, freezing, and cooking can prevent spoiling.

There are many reasons why chemicals are added to food.

Vitamins are lost when food is cooked.

What Have You Learned?

1. Another name for Vitamin C is ascorbic acid. People used to add bicarbonate of soda to the cooking water to keep the color of green vegetables from fading. What effect would bicarbonate of soda have on Vitamin C?

2. Is stale bread the same as spoiled bread?

3. What types of people would use large amounts of dehydrated food?

SKULLDUGGERY

1. Find out how the Food and Drug Administration (FDA) decides what chemicals can legally be added to foods. What substances has the FDA banned from foods? What were the reasons these substances were banned? Which cost more, foods with extra chemicals or foods without these chemicals?

When white flour is made from wheat, the husks and the germ are removed. These parts of the wheat contain much of the vitamins and minerals. The flour is "enriched" by replacing some of the lost vitamins and minerals.

How can a company say that their franks are pure beef when other ingredients are listed in fine print?

Meat tenderizer is made from a tropical fruit called a papaya. People use it to make a tasty but tough cut of meat easier to chew.

Since the cyclamate scare, what artificial sweeteners are used in diet sodas?

FOR FURTHER READING

Faber, Doris. *Miracle of Vitamins.* New York: G. P. Putnam's Sons, 1966. Nutrition and vitamins.

Kohn, Bernice. *The Organic Living Book.* New York: The Viking Press, Inc., 1972. Additives, artificial food coloring and flavor, and how to avoid them. Also organic gardening and cooking.

Tannenbaum, Beulah, and Myra Stillman. *Understanding Food: Chemistry of Nutrition.* New York: McGraw-Hill, Inc., 1962. The chemistry of food.

Appendix 1
The Metric System

Nearly the whole world uses the metric system to measure length and mass. It is easier to use than the English system. Take length, for example. If you use the English system, you may say you are five feet, four inches tall (5 ft, 4 in). You use two kinds of measure, feet and inches, to tell your height. If someone asks, "How much is that in inches?" you have to do some arithmetic:

$$5 \text{ ft} \times 12 \text{ in per ft} = 60 \text{ in}$$
$$60 \text{ in} + 4 \text{ in} = 64 \text{ in}$$

If you use the metric system, you say you are 163 centimeters tall. If someone asks, "How much is that in meters?" you can answer right away, "1.63." Notice that all you do is move the decimal point.

Because the metric system is easier, England and Canada are officially changing to it. The United States is the only large country that still uses English units officially, but plans are being made to change.

The basic unit of length is the **meter** (MEE-ter; abbreviation, m). A long step by an average person is about a meter long. Look at a meter stick to get an idea of its size. The meter stick is divided into 100 parts. Each part is called a **centimeter** (CEN-tuh-mee-ter; abbreviation, cm). Each centimeter is divided into 10 parts. They are called **millimeters** (MIL-uh-*mee*-ters; abbreviation, mm). One **kilometer** (KIL-uh-*mee*-ter; abbreviation, km) is 1000 m. 100 km is a little more than 60 miles.

The basic unit of mass is the **kilogram** (KIL-uh-gram; abbreviation, kg). This is defined as the mass of a special cylinder kept in France. See Figure 2-11. A quart of water has a mass of about one kilogram. The kilogram is divided into 1000 smaller parts called **grams** (abbreviation, g).

Summary:

centi- means $^1/_{100}$

milli- means $^1/_{1000}$

kilo- means 1000

1 cm = $^1/_{100}$ m = 0.01 m

1 mm = $^1/_{1000}$ m = 0.001 m

1 km = 1000 m

1 kg = 1000 g

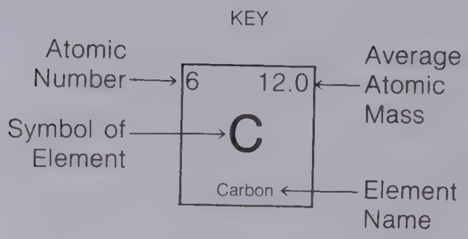
WHAT HAVE YOU LEARNED?

1. How long is this page in centimeters? Guess, and then measure it. Change the length to meters. Change it to millimeters.

2. Guess your height in centimeters. Have someone help you to measure it. What is your height in millimeters? in meters?

3. Guess the mass of this book in kilograms. Use a balance to find its mass in grams. What is this in kilograms?

Appendix 2
The Periodic Table



COLUMNS ⟶ ROWS ↓	I	II						
1	1 1.0 H Hydrogen							
2	3 6.9 Li Lithium	4 9.0 Be Beryllium						
3	11 23.0 Na Sodium	12 24.3 Mg Magnesium						
4	19 39.1 K Potassium	20 40.1 Ca Calcium	21 45.0 Sc Scandium	22 47.9 Ti Titanium	23 50.9 V Vanadium	24 52.0 Cr Chromium	25 54.9 Mn Manganese	26 55.8 Fe Iron	27 58.9 Co Cobalt
5	37 85.5 Rb Rubidium	38 87.6 Sr Strontium	39 88.9 Y Yttrium	40 91.2 Zr Zirconium	41 92.9 Nb Niobium	42 95.9 Mo Molybdenum	43 99 Tc Technetium	44 101.1 Ru Ruthenium	45 102.9 Rh Rhodium
6	55 132.9 Cs Cesium	56 137.3 Ba Barium	57–71* see below	72 178.5 Hf Hafnium	73 180.9 Ta Tantalum	74 183.9 W Tungsten	75 186.2 Re Rhenium	76 190.2 Os Osmium	77 192.2 Ir Iridium
7	87 223 Fr Francium	88 226 Ra Radium	89–103** see below	104 (unnamed)	105 (unnamed)				

*Lanthanide Series	57 138.9 La Lanthanum	58 140.1 Ce Cerium	59 140.9 Pr Praseodymium	60 144.2 Nd Neodymium	61 147 Pm Promethium	62 150.4 Sm Samarium	63 152 Eu Europium
**Actinide Series	89 227 Ac Actinium	90 232.0 Th Thorium	91 231 Pa Protactinium	92 238.0 U Uranium	93 237 Np Neptunium	94 242 Pu Plutonium	95 243 Am Americium

			III	IV	V	VI	VII	VIII ← COLUMNS	ROWS ↓
								2 4.0 He Helium	1
			5 10.8 B Boron	6 12.0 C Carbon	7 14.0 N Nitrogen	8 16.0 O Oxygen	9 19.0 F Fluorine	10 20.0 Ne Neon	2
			13 27.0 Al Aluminum	14 28.1 Si Silicon	15 31.0 P Phosphorus	16 32.1 S Sulfur	17 35.5 Cl Chlorine	18 39.9 Ar Argon	3
28 58.7 Ni Nickel	29 63.5 Cu Copper	30 65.4 Zn Zinc	31 69.7 Ga Gallium	32 72.6 Ge Germanium	33 74.9 As Arsenic	34 79.0 Se Selenium	35 79.9 Br Bromine	36 83.8 Kr Krypton	4
46 106.4 Pd Palladium	47 107.9 Ag Silver	48 112.4 Cd Cadmium	49 114.8 In Indium	50 118.7 Sn Tin	51 121.8 Sb Antimony	52 127.6 Te Tellurium	53 126.9 I Iodine	54 131.3 Xe Xenon	5
78 195.1 Pt Platinum	79 197.0 Au Gold	80 200.6 Hg Mercury	81 204.4 Tl Thallium	82 207.2 Pb Lead	83 209.0 Bi Bismuth	84 210 Po Polonium	85 210 At Astatine	86 222 Rn Radon	6

64 157.3 Gd Gadolinium	65 158.9 Tb Terbium	66 162.5 Dy Dysprosium	67 164.9 Ho Holmium	68 167.3 Er Erbium	69 168.9 Tm Thulium	70 173.0 Yb Ytterbium	71 175.0 Lu Lutetium
96 247 Cm Curium	97 247 Bk Berkelium	98 251 Cf Californium	99 254 Es Einsteinium	100 253 Fm Fermium	101 256 Md Mendelevium	102 255 No Nobelium	103 256 Lr Lawrencium

Appendix 3
How to Make a Graph

A graph shows how two things are related to each other. For example, the graph on page 439 shows how the speed of a falling ball is related to the time since it started to fall.

While you read this appendix, answer the questions. This will help you learn how to make a graph. (1) What happens to the speed of the ball as time increases?

The two things in a graph that change are called **variables.** On this graph, the variables are time and the speed of the ball.

The up-and-down line at the left side of the graph is called the **vertical axis.** The line at the bottom of the graph is called the **horizontal axis.** (2) Which variable is marked on the vertical axis in this graph? Which on the horizontal axis?

The vertical axis is used for the variable that depends on the other one. The speed of the ball depends on how long it has been falling, so speed goes on the vertical axis.

Follow these steps when you make a graph:

Step 1: Decide which variable goes on the horizontal axis and which goes on the vertical axis. Put the name of each variable on its axis. In this graph the horizontal axis is marked, ''Time in seconds.'' Notice that the name on the axis gives both the variable (time) and the unit (seconds) in which it was measured. (3) What is the unit on the vertical axis?

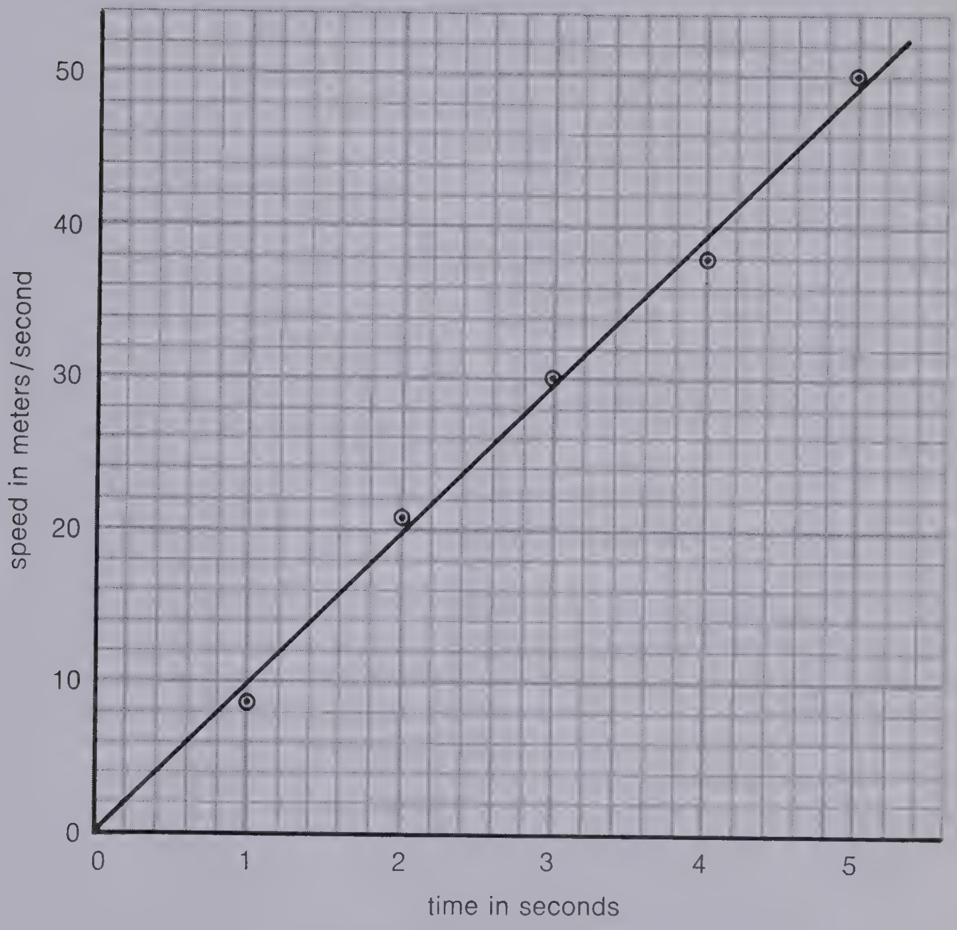
Step 2: Choose a scale that will stretch the horizontal variable more than halfway across the page. Mark the axis with numbers to show the scale. (4) In this graph, how many divisions make one second? What does one division equal?

Step 3: Choose a scale that will stretch the vertical variable more than halfway up the page. Mark the axis with numbers to show the scale. Notice that it is not necessary to label every line. Notice also that the scales in this graph are easy to use. A scale with four divisions equal to 25 meters per second, for example, would be hard to use. Each division would be equal to 6.25 meters per second. (5) In this graph, what does one vertical division equal?

Step 4: Locate each point on the graph in pencil. Use a very sharp pencil. Then look at all of the points to be sure each one is in the proper place. Now ink in each point and draw a small circle around it, also in ink. This is the only part of the graph that must be in ink. (6) How many points are located on this graph?

Step 5: Decide whether your points belong on a straight line or a curve. If they belong on a straight line, use a ruler to draw it very lightly. A transparent ruler is best for this. If the points seem to make a curve, draw a smooth curve very lightly. The line will probably not go exactly through all of the points because of errors of measurement. Do not try to force it through the points. You have the points in ink, so if you do not like the line you have drawn you can erase it and try again. When you like the line you have drawn, darken it. (7) How many points does the line go through in this graph?

Step 6: Give your graph a title. (8) What is the title of this graph?



Speed of a falling ball at different times

GLOSSARY

acid A substance that forms hydrogen ions (H^+) when it dissolves in water.

active An active substance reacts easily with other substances.

alcohol An alcohol has a formula like a hydrocarbon, but it has an OH group instead of one of the hydrogen atoms.

alloy A mixture of metals or a mixture of metals and non-metals. (Steel is an alloy made by adding other substances to iron.)

amino acid A compound that contains both the COOH group and an NH_2 group (the amino group.)

ammeter A device that measures current.

ampere The unit of current.

antinode Where crossing waves work together to make larger waves.

atom The smallest particle that can be identified as a particle of an element.

atomic mass The number of protons and neutrons in an atom.

atomic number The number of protons in an atom.

balanced forces Forces that cancel each other out.

base A substance that forms hydroxide ions (OH^-) when it dissolves in water.

battery Two or more dry cells connected together.

boiling point The temperature at which a liquid changes into a gas.

bright line spectrum A spectrum with only a few colors.

calorie (abbreviation, cal) The amount of heat needed to raise the temperature of one gram of water one Celsius degree.

carbohydrate A group of organic compounds made only from carbon, hydrogen, and oxygen. The most common carbohydrates are sugars and starches.

catalyst A substance that is added to a reaction to speed it up.

Celsius The Celsius scale of temperature is used in almost all of the countries of the world, and in scientific work. On this scale, water boils at 100°C and freezes at 0°C.

charged An object is charged if it has unequal numbers of protons and electrons.

chemical equation A chemical equation uses formulas to show what chemical reaction has taken place.

chemical reaction A change that forms new substances with different properties.

chromatographs The spots on the filter paper used for paper chromatography.

circuit breakers Magnetic switches that are sometimes used instead of fuses. They open by themselves when the current is too big.

circuit diagram A simple picture of an electric circuit, using symbols.

classification Dividing things into groups according to their properties.

combining capacity The number of electrons that an atom of an element loses, gains, or shares in forming compounds.

combustion Burning, the rapid reaction of oxygen with a substance.

compass A magnet that turns inside a case marked with the directions.

composition The relative amount of each element in a compound.

compound A substance that can be broken down into two or more different substances.

concentrated solution A large amount of material dissolved in a little water (or some other material).

conductors Materials that let electrons move. A good conductor is a bad insulator.

continuous spectrum The spectrum of light from a source that has all the colors.

control The part of the experiment you do not change.

cubic centimeter (abbreviation, cm^3) A standard unit of volume. It is the volume of a cube that is one centimeter on each side.

current in a wire A stream of moving electrons.

degree A unit of temperature. To know how big the unit is, you must know which temperature scale you are using.

dehydration Removing water from a material.

density The mass of a unit volume of a substance.

dilute solution A small amount of material dissolved in a lot of water (or some other material).

dipping compass A compass in which the magnet is hung so that it can move up and down like a seesaw, but not right and left.

direction of an electric field The direction of the force on a positively-charged particle in the field.

direction of a magnetic field The direction in which the N end of a compass needle points.

displacement of water A method of measuring volume by comparing the volume of water in a container before and after placing an object in the water.

domain One of the tiny magnets making up a magnetic material. If the domains are all lined up in the same direction, the material is a magnet.

double throw switch There are two ways to close a double throw switch and complete the circuit.

efficient In an efficient machine, the work output is almost as great as the work input.

electric circuit A complete path for electrons. If you start in one place and follow the path, you come back to the beginning.

electric field The space around a charged object. The field is strong near the object. It is weaker farther away, but never zero.

electromagnet A coil of wire wound around an iron core. It is a magnet only when the current is on.

electrons Tiny particles with a negative charge. They move around the nucleus of an atom.

element A substance that cannot be broken down into different substances.

enzyme An organic catalyst.

ester The product of a reaction between an organic acid and an alcohol.

Fahrenheit The Fahrenheit scale of temperature is used in the United States. On this scale, water boils at 212°F and freezes at 32°F.

focal length The image distance for a distant object.

focusing Some lenses can bend rays of light and bring them together. This is called focusing the rays.

force A force either changes the speed of an object, changes the shape of an object, or changes the direction of an object's motion. A force always acts in a particular direction.

force of gravity The force that attracts any two masses toward each other.

formula A way of showing the composition of a substance by using symbols.

frame of reference The background that you pretend is not moving.

freezing point The temperature at which a liquid changes to a solid.

friction A force that opposes slipping.

fulcrum The point around which a seesaw or other lever turns.

galvanized When a metal is protected by coating it with zinc, it is said to be galvanized.

generator A machine that gives energy to electrons.

graduate (or graduated cylinder) A special container used to measure volume.

gram (abbreviation, g) A unit of mass, $^1/_{1000}$ of a kilogram.

grounding A way to get rid of a charge. To do it you touch all of the charged object to a gas pipe or a water pipe.

heat The energy of moving particles.

hydrocarbon A compound made only from carbon and hydrogen.

hypothesis A guess used to explain your observations.

image A picture of an object formed by bending light rays, usually with the help of a lens or a mirror.

image distance The distance from the lens to the screen where the image is focused.

impure substance A material that is almost all one kind of matter. It contains small amounts of matter that are different from the substance.

indicator A substance that changes color in the presence of acids or bases.

input distance The distance the input force of a machine moves the load.

input force The force applied to a machine.

insulation The covering on a wire that keeps electrons from getting out.

insulators Materials that keep electrons from moving. A good insulator is a bad conductor.

interpretation A guess why or how something happens.

ion A particle with unequal numbers of protons and electrons.

ionize Substances that form ions when they dissolve in water are said to ionize.

irregular solid A solid with a shape that cannot be measured simply.

kilocalorie 1000 calories. When people talk about the calories in food, they mean kilocalories.

kilogram (abbreviation, kg) The standard unit of mass. It is defined as the mass of a particular piece of metal.

kinetic energy The energy of motion.

law of conservation of energy Energy never really disappears. It only changes from one form to another.

law of torques An object that can turn will balance if the clockwise torque equals the counterclockwise torque.

lever Anything stiff that turns when a force is applied to it.

lever arm The distance from the fulcrum to the force that causes the turning.

liter A unit of volume in the metric system. It is a little larger than a quart.

litmus An indicator that is blue in a base and pink in an acid.

load In an electric circuit, the load is whatever is plugged in to use the energy.

longitudinal wave A wave in which the particles go back and forth in the same direction as the wave.

lubricant A slippery substance that decreases friction.

machine Anything that makes it easier or more convenient to use a force to move something.

magnetic fields Magnetic fields exert forces on objects made of magnetic materials.

magnetic materials Materials that are attracted by magnets.

main switch The switch that turns off everything in a circuit.

mass Mass is measured by how hard it is to make something go faster or slower.

mechanical advantage (abbreviation, MA) The mechanical advantage of a machine is the output force divided by the input force.

melting point The temperature at which a solid changes to a liquid.

meniscus The curved surface of a liquid in a container.

metal An element that loses electrons when it reacts. Metals usually are hard and shiny. They conduct electricity and heat.

metric system The metric system of measuring uses the meter for length, the kilogram for mass, the second for time, and the newton for force.

milliliter (abbreviation, ml) $\frac{1}{1000}$ of a liter.

mineral To a food scientist, minerals are ions of metallic and non-metallic elements that your body uses in small amounts.

mixture A mixture is made of two or more different substances. Each substance keeps its own properties.

model A simple picture or object that helps you think about how something looks or how it works.

negative electric charge An object with a negative electric charge has more electrons than protons.

neutral When you talk about electric charges, neutral means "without a charge." A neutral object has just as many protons as electrons. When a solution is neutral, it is neither acidic nor basic.

neutrons Tiny particles with no charge, found in the nucleus of an atom.

newton (abbreviation, N) The unit of force in the metric system.

newton-meter The unit of work and of the moment of a force. It combines force and distance.

Newton's first law of motion If an object is not moving, it will not move unless an unbalanced force is applied to it. If an object is moving, it will keep on moving at the same speed in a straight line unless an unbalanced force is applied to it.

Newton's law of universal gravitation Every mass in the universe attracts every other mass. The force is greater when the masses are close together. It is also greater when the masses are greater.

Newton's second law of motion If an unbalanced force acts on an object, it changes the speed or direction of the motion. The greater the mass of the object, the greater the force needed to change the motion a certain amount. The faster the speed or direction changes, the greater the force that is needed.

Newton's third law of motion For every push, there is an equal push back. For every pull, there is an equal pull back.

noble gases A group of non-metallic elements that will almost never react.

node Where crossing waves cancel each other out.

non-metal An element that does not have the properties of metals. Non-metals gain or share electrons when they react.

North Magnetic Pole The earth is a giant magnet. The pole in northern Canada is called the North Magnetic Pole. Actually, it is a south magnetic pole. The north poles of magnets point to it.

north pole of a magnet When a magnet hangs so that it can swing freely, the north pole (N pole) of the magnet is the end that points north.

nucleus The protons and neutrons in the center of an atom.

object distance The distance from the object you make an image of to the lens.

observation An observation is something that you discover by looking or touching or smelling or tasting or hearing.

organic acid A compound that contains a COOH group.

organic compound Any compound containing carbon.

output distance The distance a machine moves its load.

output force The force that a machine applies to its load.

oxide A compound of oxygen and another element.

paper chromatography A method used to separate a mixture. The substances in a solution separate as the solution climbs a piece of filter paper, because some are more soluble than others.

parallel When the separate loads in a circuit are arranged in parallel, you can turn off one without turning off the others.

periodic table A chart that organizes what we know about the elements. The elements are arranged in order of atomic number. Elements that have similar properties are lined up in vertical columns.

permanent magnets In permanent magnets the domains stay lined up even when the current is off.

perpetual motion If an object could move forever, and not give away any of its energy, this would be perpetual motion. This does not happen.

perpetual motion machine A perpetual motion machine could run forever, giving away energy, but not needing more energy added. This does not happen.

pH numbers The pH numbers rate how acidic or basic a solution is.

polyatomic ion A charged chemical unit made of two or more different atoms that usually stay together in reactions.

polymer A substance made of many smaller molecules attached together.

positive electric charge An object with a positive electric charge has more protons than electrons.

potential difference The potential energy between separated charges. Potential difference is sometimes called voltage.

potential energy Stored energy.

precipitate A product of a reaction that forms and then falls out of solution.

product A substance formed by a chemical reaction.

property Information about something, such as what it looks like, what it is made of, or how it acts.

protein A polymer of amino acids.

protons Tiny particles with a positive charge, found in the nucleus of an atom.

pulse When you suddenly push one end of the slinky in and back out, the movement that travels down the slinky is called a pulse.

reflection Bouncing off.

refraction The bending of light when it goes from one material to another.

regular solid Regular solids have sides that can be measured with a ruler.

repel To push away.

rust Rust is iron oxide, a compound of iron and oxygen.

salt Any compound that contains positive ions other than hydrogen, and negative ions other than hydroxide.

scientific law A scientific law tells how matter and energy behave.

series When the separate loads in a circuit are arranged in series, all the electrons that go through one load must go through all the others. When one load is turned off, they all go off.

short circuit In a short circuit, electrons make a complete path without going through the load.

soft iron A kind of iron that is easily magnetized by an electric current.

solubility The mass of a material that will dissolve in 100 ml of a liquid at a particular temperature.

solution A mixture made by dissolving a material in a liquid.

source Something that gives energy to the electrons in an electric circuit.

South Magnetic Pole The earth is a giant magnet. The pole in the Antarctic is called the South Magnetic Pole. Acutally it is a north magnetic pole.

south pole of a magnet When a magnet hangs so that it can swing freely, the south pole (S pole) of the magnet is the end that points south.

spectroscope A device that separates out the colors that come from a light source.

spectrum The series of colors into which light from a source can be broken.

speed The speed of an object is the distance it travels in a unit time.

stable A stable element does not usually react with other substances.

standard unit Any unit that people have agreed to use.

standing wave A wave pattern with places that stand still.

starch A polymer formed by many glucose molecules joined in a chain.

steel Iron mixed with small amounts of other materials.

structural formula A formula that shows how atoms in a molecule are connected.

symbol Something that stands for an object or an idea.

temperature Temperature measures the average kinetic energy of particles.

temporary magnet An electromagnet.

terminals The places where wires can be connected to a cell.

terminal velocity The steady speed reached by an object falling in air, because of air resistance.

test A way to check whether a substance is present in a material or not.

theory A suggested explanation.

torque The turning effect of a force. It is the size of the force times its lever arm.

transverse wave In a transverse wave the particles go back and forth crosswise to the direction of the wave.

unit A specified amount of something (for example, mass) with which other amounts of the same thing are compared.

vibration Moving back and forth very quickly.

vitamins Organic substances your body needs in small amounts.

volt (abbreviation, V) The unit of potential difference.

voltmeter A device to measure potential difference.

volume The amount of space an object takes up.

wave A series of pulses.

wavelength The distance from one part of a wave to the next part that is just like it.

weight The weight of anything on the earth is how hard the earth pulls it.

work When a force acts through a distance, the product (force times distance) is called work.

work input The amount of work put into a machine.

work output The amount of work got out of a machine.

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